APPENDIX D
EVALUATION OF HUMAN HEALTH IMPACTS FROM FACILITY ACCIDENTS

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D.1 Introduction

This appendix provides additional information and details to support the facility accident impacts presented in Chapter 5. It includes, in Section D.2, an evaluation of the present applicability of the methodology and accident data that was reported in the *Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico (1999 SWEIS)* (DOE 1999a) for the purpose of informing the reader of differences in analysis between that document and the current site-wide environmental impact statement (SWEIS) for continued operation of Los Alamos National Laboratory (LANL). This is followed in Section D.3 with a discussion of the postulated radiological and chemical accident scenarios and their estimated impacts to workers and the public. Section D.4 discusses site-wide seismic impacts. Wildfires in the LANL vicinity, and their potential for causing the release of hazardous radiological and chemical materials is a subject of public concern. A wildfire accident scenario was analyzed and its potential impacts to workers and the public are discussed in Section D.5. The impact discussions through Section D.5 center on the general population and specific bounding individuals (the noninvolved worker and the maximally exposed individual). Section D.6 discusses the impacts to the worker directly involved in the operation being analyzed, that is, the involved worker. Section D.7 considers impacts on individuals at arbitrary distances up to 3,281 yards (3,000 meters) from each hypothesized accident source. Two computer codes were used to analyze the postulated accidents and to estimate their impacts: (1) MACCS for radiological releases; and (2) ALOHA for chemical releases. These codes are described in Sections D.8 and D.9, respectively.

It is not possible to predict whether intentional attacks would occur at LANL or at other critical facilities, or the nature of the types of attacks that might be made. Nevertheless, the National Nuclear Security Administration (NNSA) reevaluated scenarios involving malevolent, terrorist, or intentionally destructive acts at LANL in an effort to assess potential vulnerabilities and identify improvements to security procedures and response measures in the aftermath of the attacks of September 11, 2001. Security at NNSA and the U.S. Department of Energy (DOE) facilities is a critical priority for the Department, and it continues to identify and implement measures designed to defend against and deter attacks at its facilities. Substantive details of terrorist attack scenarios and security countermeasures are not released to the public, since disclosure of this information could be exploited by terrorists to plan attacks.

D.2 Data and Analysis Changes from the *1999 SWEIS*

Accident scenarios are generally chosen for analysis in an environmental impact statement to demonstrate the range of possible initiating events and impacts. Accidents resulting in severe (often bounding) consequences and risks are typically presented as well. In the case of the current SWEIS, scenarios from the *1999 SWEIS* were considered. Changes to LANL operations since 1999, or the availability of new information that could change the scenarios in the *1999 SWEIS* were incorporated. Then, new operations that have been initiated since 1999 (or that are planned to be initiated) were considered. Scenarios for these changed or new operations were chosen to demonstrate the range of possible accidents, as well as to describe bounding risks.

The differences between the *1999 SWEIS* and this SWEIS are provided in **Table D–1**. Most of the differences are the result of updated environmental (such as population and meteorology) and facility operations (facilities added, deleted or material at risk [MAR] changes) information. Additional aspects of the overall study that pertain to other environmental resource areas are addressed elsewhere in this SWEIS to the extent that they are relevant.

The first column of Table D–1 refers to an accident topic or issue discovered during the review of documented information. Designations such as RAD-01, CHEM-01 and SITE-01 refer to specific accidents that were postulated and analyzed in the *1999 SWEIS*. The relevant facilities are also identified in the column where applicable. The second column contains a qualitative description to reflect the change, if any, in scenarios since the *1999 SWEIS* was issued. The third column is an evaluation of the current information on the listed topic or issue. The information contained in Table D–1 had a dominant role in directing the course of the facility accident analyses performed for this SWEIS.

DOE identifies LANL as the highest Priority I site, which is subject to 24-month internal emergency management appraisals. DOE maintains a system of Orders, programs, guidance, and training that form the basis for maintaining, updating, and testing LANL site security to preclude and mitigate any postulated terrorist actions.

Much of the background data, such as meteorology or plume characteristics, and its use in the present analysis, are described in **Table D–2**. As indicated in the table, an offsite population distribution based on the 2000 census was determined for each LANL Technical Area (TA); this distribution was then applied to any releases from that area. Populations were considered to a distance of 50 miles (80 kilometers) from the TA.

D.3 Radiological and Chemical Accidents

This section provides information and data that supports the radiological and chemical impacts of facility accidents for each alternative presented in Chapter 5. It includes the accident frequency of occurrence and impacts, scenarios, material at risk, source terms and factors used in the calculation of source terms.

These scenarios represent potential accidents at individual facilities. External events, earthquakes or wildfires, which could impact multiple facilities, are considered in Sections D.4 and D.5, respectively.

Table D–1 Evaluation of Accident Data from the *1999 SWEIS*

Topic/Issue	*Scenario Notes*	*Evaluation*
Offsite population	None	Offsite population has increased in magnitude by 20 to 30 percent.
Modeling Methodology		Dose-to-LCF factor has increased by 20 percent (public) and 50 percent (worker). Other SWEIS modeling parameters that were not specified in the *1999 SWEIS* can affect MEI and population doses.
Meteorological Data		Post-*1999 SWEIS* meteorological data is available through 2003. Sensitivity analysis using more recent data shows increases in population dose of up to 20 percent. Chemical accident impacts would also increase.
RAD-01 TA-54, RANT	Increased source term	Reanalyzed based on scenario changes including increased source term from BIO. Now noted as RANT Outdoor Container Storage Area Fire.
RAD-02 TA-3, CMR	New CMR scenario	The *CMRR EIS* (DOE 2003a) was published after the *1999 SWEIS*. The maximum risk no action accident from that document was selected to represent CMR. The scenario is called CMR HEPA Filter Fire.
RAD-03 TA-18, GODIVA IV	No longer operating	Not analyzed because this TA-18 mission is being relocated to the Nevada Test Site. MAR that was formerly at TA-18 has been moved to the TA-55 SST Facility and is considered as part of the site-wide seismic scenarios.
RAD-04 TA-15, DARHT	Nonnuclear	Not analyzed, now a nonnuclear facility.
RAD-05 TA-21, TSFF	MAR moved to WETF	Replaced with Fire at WETF. Remaining MAR analyzed as part of site-wide seismic scenarios.
RAD-06 TA-50-37, RAMROD	Radiological facility	Not analyzed. Facility is no longer a nuclear facility and thus would not impact offsite receptors.
RAD-07 TA-50-69, WCRR	MAR decreased	Now called WCRR Outdoor Storage Area Fire. New MAR from 2003 BIO, as related in 2004 Information Document (LANL 2004).
RAD-08 TA-54, TWISP	New transuranic waste storage scenario	Replaced with Waste Storage Dome Fire. Major risk accident from DOE 2003b.
RAD-09 TA-54, TWISP	New waste storage domes scenario	Replaced with Onsite Transuranic Waste Fire Accident. Major risk accident from DOE 2003b.
RAD-10 TA-55-4, Plutonium Facility	No change	Now called Plutonium Facility Storage Container Release.
RAD-11 TA-15, DARHT	Nonnuclear	Not analyzed, now a nonnuclear facility.
RAD-12 TA-16-411	Radiological facility	Not analyzed. Facility is no longer a nuclear facility and thus would not impact offsite receptors. Remaining MAR analyzed as part of Site-wide Wildfire.
RAD-13 TA-18, Pajarito Site, Kiva #3	No longer operating	Replaced with scenario for only operating reactor, SHEBA Hydrogen Detonation. Scenario is major risk SHEBA accident scenario from the *TA-18 Relocation EIS* (DOE 2002a). MAR that was formerly at TA-18 has been moved to the TA-55 SST Facility and is considered as part of the site-wide seismic scenarios.
RAD-14 TA-55-4, Plutonium Facility	No change	Now called Plutonium Facility Ion Column Rupture.
RAD-15 TA-3-29 CMR	New CMR scenario	See RAD02. Wing Fire now considered as part of Radiological Sciences Institute.

Topic/Issue	*Scenario Notes*	*Evaluation*
RAD-16 TA-3-29, CMR	New CMR scenario	See RAD02.
SITE-01 (Rad) Site-wide Earthquake	Change in source term and components	Renamed Seismic 1. CMR source term replaced based on DOE 2003a. TA-18 source term changed based on DOE 2002a, plus movement of material from TA-18 to TA-55 (see Seismic 02). RAMROD deleted because it is no longer a nuclear facility. Decrease in TA-21 source term. Change in scenario and increase in RANT source term. No release from Waste storage domes during this event (DOE 2003b). DVRS glovebox processing campaign added (DOE 2004b). Nominally PC-2.
SITE-02 (Rad) Site-wide Earthquake	Change in source term and components	Renamed Seismic 2. Seismic 1 changes (above) carry to this scenario. Increase in WETF source term, TWISP (now Domes) scenario revised; source term increase based on all domes per DOE 2003b. Plutonium Facility releases based on 2002 BIO. Added SST Facility (material moved from TA-18 and awaiting shipment to the Nevada Test Site). Nominally PC-3.
SITE-03 (Rad) Site-wide Earthquake	Deleted	No significant scenarios beyond those of Seismic 2. Surface rupture not considered in source document (DOE 2003a).
SITE-04 (Rad) Site-wide Wildfire	Change in source term and components	Renamed Wildfire. TA-21 source terms decreased. Sigma Complex, Radiochemistry Laboratory, waste storage domes added.
CHEM-01 TA-00-1109	Deleted	Accident is no longer applicable since MAR has been moved offsite (LANL 2004).
CHEM-02 TA-3-476	Deleted	Chlorine no longer stored for water treatment (LANL 2004).
CHEM-03 TA-3-476	Deleted	Chlorine no longer stored for water treatment (LANL 2004).
CHEM-04 TA-54-216	No change	Now labeled 75 liters selenium hexafluoride from waste cylinder storage at TA-54-216 (LANL 2004).
CHEM-05 TA-54-216	No change	Now labeled 300 pounds sulfur dioxide from waste cylinder storage at TA-54-216 (LANL 2004).
CHEM-06 TA-55-4	No change	Now labeled 150 pounds of chlorine gas released outside of Plutonium Facility (LANL 2004).
Helium at TA-55-41	New	Added to represent possible asphyxiant release accident.
SITE-01 (Chem) Site-wide Earthquake	Change in source term and components	Renamed Seismic 1. Chlorine at TA-00 and TA-3 deleted, no longer at site. Phosgene and formaldehyde sources decreased.
SITE-02 (Chem) Site-wide Earthquake	Change in source term and components	Renamed Seismic 2. Seismic 1 changes carry over to this scenario. All else (TA-55 sources) unchanged from *1999 SWEIS*.
SITE-03 (Chem) Site-wide Earthquake		Same scenario as Seismic 2. SITE-03 was combined with SITE-02 to create Seismic 2.
SITE-04 (Chem) Site-wide Wildfire	Change in source term and components	Renamed Wildfire. Hydrogen cyanide from Sigma Complex added.
TA-54, DVRS	New	DVRS glovebox processing campaign scenarios are added (DOE 2004b).

Topic/Issue	***Scenario Notes***	***Evaluation***
Sealed Sources at CMR	New	Sealed source MAR at CMR added.
MDA G	New	Scenario (explosion) that could potentially affect offsite receptors chosen (see Appendix I).
Aircraft Crash	New	*1999 SWEIS* aircraft crash scenarios either MAR moved (see RAD-05), not operating (see RAD-06), or more bounding, non-aircraft crash scenario chosen for analysis (see RAD-08 and RAD-16). Aircraft crash scenario analyzed in Appendix J (Human Health Impacts section) of this SWEIS for Sealed Sources in Waste Storage Domes at TA-54, Area G. Highest risk sealed source scenario (Sealed Sources at CMR) brought forward to this appendix (see Sealed Sources at CMR above).
CMRR	Bounded by CMR	DOE 2003a considered accidents from both CMR (no action) and the replacement facility, CMRR (preferred action). The results (Tables C–3 and C–5 of that document) show that CMRR accident risks are bounded by those of CMR. Therefore, the latter is analyzed here.
WORK-01 thru -05	Not included	Involved worker accident consequences were addressed qualitatively in the *1999 SWEIS*. Designations Work-01 thru -05 dropped and replaced with discussion in Section D.6.
Criticality Scenario	Involved worker issue	Considered in 1999 SWEIS for TA-18 (facility not operating in the alternatives for this SWEIS) and qualitatively for involved workers (WORK-03). SHEBA (TA-18) criticality considered in DOE 2002a and risks to the public and non-involved worker shown (Table C–5 of that document) to be inconsequential and bounded by the SHEBA Hydrogen Detonation scenario analyzed in this SWEIS. Criticality scenario impacts are short range and affect involved workers only. Involved worker impacts are discussed in Section D.6.
Detonation of High Explosives Scenario	Involved worker issue	Considered qualitatively in 1999 SWEIS for involved workers (WORK-01). No potential for associated radionuclide or toxic chemical release consequences to public. High explosive detonation scenario impacts are short range and affect involved workers only. Involved worker impacts are discussed in Section D.6.

LCF = latent cancer fatality, MEI = maximally exposed individual, TA = technical area, RANT = Radioactive Assay and Nondestructive Test, BIO = basis of interim operation, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air, GODIVA = fast burst reactor formerly operating in TA-18, MAR = material at risk, SST = Safe Secure Transport, DARHT = Dual-Axis Radiographic Hydrodynamic Test, TSFF = Tritium Science and Fabrication Facility, WETF = Weapons Engineering Tritium Facility, RAMROD = Radioactive Materials Research, Operations, and Demonstration, WCRR = Waste Characterization, Reduction, and Repackaging Facility, TWISP = Transuranic Waste Inspectable Storage Project, SHEBA = Solution High-Energy Burst Assembly, DVRS = Decontamination and Volume Reduction System, PC = performance category, MDA = material disposal area, CMRR = Chemistry and Metallurgy Research Replacement.

Table D–2 General Analysis Assumptions Independent of Scenario

Parameter	***General Population***	***MEI, Workers***	***Comments***
MACCS2			**Version 1.13.1**
Population	SECPOP2000 (NRC 2003) 2000 census. General population distribution centered at accident source facility.	Noninvolved worker at 100 meters from source.	Facility locations from LANL 2006. MEI and noninvolved worker using "peak dose at a distance" MACCS2 results.
Population Ring Boundaries	1, 2, 3, 4, 5, 10, 20, 30, 40, 50 miles	Not applicable	General population to 50 miles.
Inhalation and external exposure from plume	Yes	Yes	
Inhalation and external exposure from deposition and resuspension	Yes	No	MEI and noninvolved worker are short-term exposures.
Breathing rate	0.000347 cubic meters per second	0.000347 cubic meters per second	DOE 1992.
Exposure from agricultural pathway, except tritiated water, strontium-90 and cesium-137	No	No, due to short exposure time.	Plutonium and uranium chief inhalation risks.
Exposure from agricultural pathway, tritiated water, strontium-90, and cesium-137	Yes, HTO estimated using CAP88. Derived factor.	No, due to short exposure time.	Ratio of ingestion to inhalation as determined from unit release of HTO using CAP88 (EPA 2005). No worker or individual ingestion pathway.
Evacuation	No	No	Assume no protective actions taken.
Relocation	No	No	Assume no protective actions taken.
Cloud shielding factor	0.75	1	General population from Chanin and Young 1997.
Protection factor for inhalation	0.41	1	General population from Chanin and Young 1997.
Skin protection factor	0.41	1	General population from Chanin and Young 1997.
Ground shielding factor	0.33	1	General population from Chanin and Young 1997. No deposition for workers.
Groundshine weathering coefficients	0.5, 0.5	0.5, 0.5	Chanin and Young 1997. Not applicable to workers.
Groundshine weathering coefficient half-lives	1.6×10^{7}, 2.8×10^{9} seconds	1.6×10^{7}, 2.8×10^{9} seconds	Chanin and Young 1997. Not applicable to workers.
Resuspension concentration coefficient	10^{-5}, 10^{-7}, 10^{-9} per meter	10^{-20}, 10^{-20}, 10^{-20} per meter	General population from Chanin and Young 1997. No resuspension for workers.
Resuspension concentration coefficient half-lives	1.6×10^{7}, 1.6×10^{8}, 1.6×10^{9} seconds	1.6×10^{7}, 1.6×10^{8}, 1.6×10^{9} seconds	0.5, 5, and 50 years respectively (Chanin and Young 1997). Not applicable to workers.
Wet deposition	Yes	No	No wet deposition for workers. No wet deposition of noble gases (Chanin and Young 1997).
Dry deposition	Yes	No	No dry deposition for workers (conservative). No dry deposition of noble gases (Chanin and Young 1997).
Washout coefficient	0.000095, 0.8	0.000095, 0.8	Chanin and Young 1997. Not applicable to workers and MEI.

Parameter	***General Population***	***MEI, Workers***	***Comments***
Deposition velocity	.01, .005, .001 meters per second	.01, .005, .001 meters per second	Unfiltered particulates, tritiated water, filtered particulates, respectively. Not applicable to workers and MEI.
Long-term exposure period (resuspension)	317 years (1×10^{10} sec)	317 years (1×10^{10} sec)	Maximum allowed by MACCS2. Not applicable to workers and MEI.
Sigma-y, Sigma-z (dispersion parameters)	Tadmor-Gur Tables	Tadmor-Gur Tables	Chanin and Young 1997.
Surface roughness length correction	1.27	1.66	Corresponds to z0=10 centimeters (rural) for general population and z0=38 centimeters (DOE 2004b) for workers.
Plume meander time base	600 seconds	600 seconds	Chanin and Young 1997.
xpfac1	0.2	0.01	Plume meander exponential factor for time less than break point (1 hour). General population from DOE 1992, workers set to .01 (minimum value allowed by MACCS), so no plume meander for 1 hour (conservative).
xpfac2	0.25	0.25	Chanin and Young 1997; plume meander exponential factor for times greater than 1 hour.
Plume segment reference time	0	0	Plume segment reference at leading edge of plume (for dispersion, deposition, decay calculations).
TA releases for which TA-6 MET Tower data are used	[3], 6, 8, 9, [16], 22, 35, 40, 43, 48, [50], 52, [55], 59, 60, 61, 63, 64, 66, 69	[3], 6, 8, 9, [16], 22, 35, 40, 43, 48, [50], 52, [55], 59, 60, 61, 63, 64, 66, 69	Closest MET Tower to TAs. All TAs with workers listed; TAs with accident releases in *1999 SWEIS* indicated with brackets [ ].
TA releases for which TA-49 MET Tower data are used	11, [15], 33, 36, 39, 49	11, [15], 33, 36, 39, 49	Closest MET Tower to TAs. All TAs with workers listed; TAs with accident releases in *1999 SWEIS* indicated with brackets [ ].
TA releases for which TA-53 MET Tower data are used	0, [21], 46, 51, 53	0, [21], 46, 51, 53	Closest MET Tower to TAs. All TAs with workers listed; TAs with accident releases in *1999 SWEIS* indicated with brackets [ ].
TA releases for which TA-54 MET Tower data are used	[18], [54]	[18], [54]	Closest MET Tower to TAs. All TAs with workers listed; TAs with accident releases in *1999 SWEIS* indicated with brackets [ ].
Meteorological dataset	2003	2003	Overall year of maximum worker and general population dose for the years 1995 through 2003 for unit ground level release of plutonium-239. All TA MET data for 2003 within 11 percent of maximum year (1995 through 2003) except TA-46 (16 percent).
Atmospheric mixing height	350, 550, 500, 380; 1,500, 3,400, 4,000, 2,200 meters	350, 550, 500, 380; 1,500, 3,400, 4,000, 2,200 meters	Morning-winter, spring, summer, fall; afternoon-winter, spring, summer, fall (Holzworth 1972).
Wind shift without rotation	Yes	Yes	Plume direction follows wind direction every hour.

Parameter	General Population	MEI, Workers	Comments
metcod	5	5	Stratified random samples for each day of the year (see nsmpls).
nsmpls	24	24	24 MET samples per day (sample each hour).
Boundary conditions used in last ring	Yes	No	General population boundary conditions (rainfall) conservatively chosen so that releases are accounted for within modeled area. Sensitivity shows that not including boundary conditions (open boundary) results in decrease of 12 percent in median population dose and no change in extreme population dose for TA-6.
Model boundary mixing height	1,600 meters	1,600 meters	Average of seasonal mixing heights as given in MET files.
Model boundary stability class and wind speed	D-2.2 meters per second	D-2.2 meters per second	50 percent MET conditions (see average MET conditions below). Not applicable to workers.
Model boundary rain fall rate	23 millimeters per hour	0 millimeters per hour	Maximum hourly rate from all 2003 MET files (noted at TA-53 and 54), conservative. Not applicable to workers.
Dose conversion factors	FGR 11,12	FGR 11,12	Increase tritiated water inhalation by 50 percent to account for skin absorption (EPA 1988, EPA 1993).
Presented dose results	TEDE-mean	TEDE-mean	
Health risk	0.0006	0.0006	Fatal cancers per rem (total effective dose equivalent) (DOE 2003c).
ALOHA			**Version 5.3.1.**
Ground roughness length	38 centimeters	38 centimeters	DOE 2004b. ALOHA will default to vertical dispersion parameter (Sigma-z) values consistent with urban environment for the indicated roughness length, z0, of 38 centimeters. For z0 less than 20 centimeters, ALOHA defaults to a rural environment. Distances of interest expected to be close to release. General population uses same parameters as workers.
Meteorological measurement height	10 meters	10 meters	Consistent with MACCS MET data files.
Humidity	50 percent	50 percent	DOE 2004c. Within range for LANL (LANL 2006).
Median MET conditions	D-2.2	D-2.2	Stability class and wind speed in meters per second. 50 percent x/q at 2,000 meters, typical distance of interest. Minimum median wind speed from any MET Tower for 2003 (noted at TA-6). Other areas range up to D-2.8.
Median MET conditions (Wildfire)	D-3.5	D-3.5	Stability class and wind speed in meters per second. 50 percent x/q at 2,000 meters, typical distance of interest. Minimum median wind speed from any MET Tower for cumulative period 2000 through 2003 (noted at TA-49) for months of April through June. Other areas range up

Parameter	*General Population*	*MEI, Workers*	*Comments*
			to D-4.0 (for TA-53).
Date and time, median MET conditions	June 22 - 1 p.m.	June 22 - 1 p.m.	DOE 2004c (summer, midday). Consistent with hours of average MET conditions from 2003 TA-6 MET tower data.
Air temperature, median MET conditions	81 degrees Fahrenheit	81 degrees Fahrenheit	LANL 2006.
Cloud cover, median MET conditions	10 tenths	10 tenths	Complete cloud cover; chosen to be consistent with other median meteorological conditions and stability class D.
Inversion height (mixing height), median MET conditions	4,000	4,000	Meters. Summer afternoon mixing height (see "Atmospheric Mixing Height," above), consistent with date and time.
Presented effects	Distance to ERPG-2 and 3	Distance to ERPG-2 and 3	DOE 2004c.

MEI = maximally exposed individual, HTO = tritiated water, TA = technical area, FGR = Federal Guidance Report, TEDE = total effective dose equivalent, ERPG = Emergency Response Planning Guideline.

Note: To convert meters to feet, multiply by 3.28; from miles to kilometers, multiply by 1.609.

D.3.1 Radiological and Chemical Scenarios and Source Terms

The accident scenarios and source terms used to calculate the radiological and chemical accident impacts are shown in **Table D–3**.

The evolution of choosing these scenarios is described in Table D–1. As described there, most of these scenarios evolved from those analyzed in the *1999 SWEIS*.

The Decontamination and Volume Reduction System (DVRS) is a new operation that was not considered in the *1999 SWEIS*. The impacts from an operational spill at DVRS are presented to depict the consequences of a relatively high probability operational accident. The forklift collision and spill due to building fire scenario is included because it represents high consequence and high risk (relative to other DVRS scenarios) impacts to the general public and workers.

Storage of sealed sources represents a potential source of radionuclides not included in the earlier *1999 SWEIS*. These radionuclides (for example cobalt-60 and cesium-137) represent external gamma radiation dose risks, unlike those in most other scenarios (for example tritium, uranium, and transuranics) which represent chiefly internal dose risks. A scenario that results in the largest risk from these sources, seismic event and fire at Chemistry and Metallurgy Research Building (CMR) impacting sealed sources, is included. The doses to individuals very close to the source (for example the noninvolved worker) include a component from direct (external) exposure to exposed source material. Appendix J further describes the calculation of direct exposure to sealed sources in an accident and includes additional sealed source scenarios.

Material Disposal Area (MDA) cleanup was not an action considered in the *1999 SWEIS*. Appendix I of the current SWEIS describes proposed actions for MDAs, and contains estimated impacts to offsite and worker receptors from severe accidents (relative to other MDA scenarios) at MDA G (maximum inventory MDA) and MDA B (close proximity to offsite receptors). The consequences and risks from the greater of the two are included in the Expanded Operations Alternative in this section.

D.3.2 Radiological Accident Impacts

Estimated facility accident impacts are represented in terms of consequences and risks. All consequences assume that the accident has occurred and, therefore, the probability or frequency of the accident occurring is not taken into account. The risk of an accident does reflect the probability or frequency of occurrence and is calculated by multiplying the accident's frequency of occurrence by the accident's consequences. Dose consequences are estimated for the maximally exposed individual (MEI) (reported in rem) located at the nearest site boundary, a noninvolved worker (reported in rem) located 328 feet (100 meters) from the accident, and the offsite population (reported in person-rem) out to a distance of 50 miles (80 kilometers). Impacts at locations of public access closer than the nearest site boundary are also discussed.

Table D–3 Facility Accident Source Term Data

Accident Phase	*Nuclide*	*MAR (curies or grams)*	*MAR*	*Damage Ratio*	*Airborne Release Fraction*	*Respirable Fractions*	*Airborne Release Rate (per hour)*	*Leak Path Factor*	*Source Term (units of MAR)*	*Release Duration (minutes)*	*Plume Heat (mega-watts)*	*Release Height (meters)*	*Wake?*
Identifier: RAD01. **Scenario:** RANT Outdoor Container Storage Area Fire (TA-54-38).													
Combustible													
Spilled and expelled	Plutonium [a] Equivalent	grams	9,700	1	0.001	0.3	–	1	2.91	–	–	0	No
Burning			9,690	1	0.01	1	–	1	96.9	–	–	0	No
Contained in drum (burning)			10,600	1	0.0005	1	–	1	5.29	–	–	0	No
Noncombustible													
Spilled and expelled	Plutonium Equivalent	grams	17,500	1	0.001	0.1	–	1	1.75	–	–	0	No
Burning			17,500	1	0.006	0.01	–	1	1.05	–	–	0	No
Contained in drum (burning)			19,100	1	0	0	–	1	0	–	–	0	No
Total													
Spilled and expelled	Plutonium Equivalent	grams	–	–	–	–	–	–	4.66	1	0	0	No
Burning (high heat)			–	–	–	–	–	–	51.6	60	12	0	No
Burning (smoldering)			–	–	–	–	–	–	51.6	60	0.1	0	No
Resuspension			27,000	1	–	1	0.00004	1	25.9	1,440	0	0	No
Identifier: WETF. **Scenario:** WETF Fire (TA-16-205).													
Fire	Tritiated Water	grams	1,000	1	1	1	–	1	1,000	60	0	23	Yes
Fire	Plutonium-238		5.00	1	0.0005	1	–	1	0.0025	60	0	23	Yes
Suspension	Plutonium-238		5.00	1	–	1	0.00004	1	0.0048	1,440	0	0	Yes
Identifier: RAD07. **Scenario:** WCRR Outdoor Storage Area Fire (TA-50-69).													
Fire (high heat)	Plutonium Equivalent	curies	500	0.35	0.0005	1	–	1	0.0875	60	1	0	No
Fire (smoldering)			500	0.35	0.0005	1	–	1	0.0875	60	0.1	0	No
Resuspension			1,000	0.35	–	1	0.00004	1	0.336	1,440	0	0	No

Accident Phase	*Nuclide*	*MAR (curies or grams)*	*MAR*	*Damage Ratio*	*Airborne Release Fraction*	*Respirable Fractions*	*Airborne Release Rate (per hour)*	*Leak Path Factor*	*Source Term (units of MAR)*	*Release Duration (minutes)*	*Plume Heat (mega-watts)*	*Release Height (meters)*	*Wake?*
Identifier: DOMEF **Scenario:** Waste Storage Dome Fire (TA-54).													
Combustible													
Burning expelled in lid loss	Plutonium Equivalent	curies	3,380	0.123	0.01	1	–	1	4.15	60	0	0	No
Burning (in drums)			3,380	0.877	0.0005	1	–	1	1.48	60	0	0	No
Noncombustible													
Burning	Plutonium Equivalent	curies	9,210	1	0.006	0.01	–	1	0.553	60	0	0	No
Total													
Burning	Plutonium Equivalent	curies	–	–	–	–	–	–	6.18	60	0	0	No
Impact release			12,600	0.123	0.001	1	–	1	1.55	1	0	0	No
Identifier: DOMET **Scenario:** Onsite Transuranic Waste Fire Accident (TA-54).													
Initial (expelled)	Plutonium Equivalent	curies	1,100	1	0.001	0.3	–	1	0.33	1	0	0	No
Uncontained burn (high heat)			1,100	1	0.01	1	–	0.5	5.49	60	15.3	0	No
Uncontained burn (smoldering)			1,100	1	0.01	1	–	0.5	5.49	60	0.1	0	No
Suspension			1,090	1	–	1	0.00004	1	1.04	1,440	0	0	No
Identifier: RAD10. **Scenario:** Plutonium Facility Storage Container Release (TA-55-4).													
Container drop	Weapons Grade Plutonium [b]	grams	4,500	1	0.002	0.3	–	1	2.70	30	0	0	Yes
Resuspension			4,500	1	–	1	0.00004	1	4.32	1,440	0	0	Yes
Identifier: RAD14. **Scenario:** Plutonium Facility Ion Column Rupture (TA-55-4).													
Solution flashing (nitrate)	Weapons Grade Plutonium	grams	246	1	0.01	0.6	–	1	1.48	10	0	9.14	Yes
Resin bed burning (oxide)			1,000	0.1	0.01	0.9	–	1	0.9	10	0	9.14	Yes
Suspension of nitrate			244	1	–	1	0.0000004	1	0.00234	1,440	0	9.14	Yes
Suspension of oxide			999	0.1	–	0.9	0.00004	1	0.0863	1,440	0	9.14	Yes
Total													
Initial release	Weapons Grade Plutonium	grams	–	–	–	–	–	–	2.38	10	0	9.14	Yes
Suspension			–	–	–	–	–	–	0.0887	1,440	0	9.14	Yes

Accident Phase	***Nuclide***	***MAR (curies or grams)***	***MAR***	***Damage Ratio***	***Airborne Release Fraction***	***Respirable Fractions***	***Airborne Release Rate (per hour)***	***Leak Path Factor***	***Source Term (units of MAR)***	***Release Duration (minutes)***	***Plume Heat (mega-watts)***	***Release Height (meters)***	***Wake?***
Identifier: DVRS01. **Scenario:** DVRS Operational Spill (TA-54).													
	Plutonium Equivalent	curies	1,100	1	0.001	0.3	–	1	0.33	10	0	0	Yes
Identifier: DVRS05. **Scenario:** DVRS Building Fire and Spill Due to Forklift Collision (TA-54).													
	Plutonium Equivalent	curies	1,100	1	0.01	1	–	1	11.0	120	0.1	0	Yes
Identifier: SHEBA. **Scenario:** SHEBA Hydrogen Detonation (TA-18-168) No Action Only.													
Metal	Plutonium Equivalent	grams	9,020	1	0.0005	0.5	–	1	2.25	–	–	–	No
Ceramic			924	1	0.005	0.4	–	1	1.85	–	–	–	No
Liquid			9.00	1	0.00005	0.8	–	1	0.00036	–	–	–	No
Powder			0.06	1	0.005	0.4	–	1	0.00012	–	–	–	No
Gas			0.00	1	1.00	1	–	1	0	–	–	–	No
Total													
High Heat	Plutonium Equivalent	grams	–	–	–	–	–	–	2.05	60	2.1	1.5	No
Smoldering			–	–	–	–	–	–	2.05	60	0.1	0	No
Identifier: CMR02. **Scenario:** CMR HEPA Filter Fire (TA-3-29).													
Fire (high heat)	Plutonium Equivalent	curies	0.613	1	0.4	1	–	0.5	0.123	26.7	1.696	1.5	Yes
Fire (smoldering)			0.613	1	0.4	1	–	0.5	0.123	26.7	0.1	1.5	Yes
Identifier: SEAL2CF. **Scenario:** Fire Impacting Sealed Source, Wing 9 at CMR Building. Expanded Operations Only.													
Impact	Cobalt-60	curies	3,420,000	0.05	0.001	0.3	–	1	51.3	30	2.04	0	No
	Strontium-90		580,000	0.05	0.001	0.3	–	1	8.70	30	2.04	0	No
	Cesium-137		23,500,000	0.05	0.001	0.3	–	1	353	30	2.04	0	No
	Iridium-192		26,400,000	0.05	0.001	0.3	–	1	396	30	2.04	0	No
	Radium-226		87,400	0.05	0.001	0.3	–	1	1.31	30	2.04	0	No
	Curium-244		2,850	0.05	0.001	0.3	–	1	0.0428	30	2.04	0	No
	Californium-252		6,100	0.05	0.001	0.3	–	1	0.0915	30	2.04	0	No

Accident Phase	***Nuclide***	***MAR (curies or grams)***	***MAR***	***Damage Ratio***	***Airborne Release Fraction***	***Respirable Fractions***	***Airborne Release Rate (per hour)***	***Leak Path Factor***	***Source Term (units of MAR)***	***Release Duration (minutes)***	***Plume Heat (mega-watts)***	***Release Height (meters)***	***Wake?***
Fire (high heat)	Cobalt-60	curies	3,420,000	0.05	0.006	0.01	–	0.5	5.13	30	2.04	0	No
	Strontium-90		580,000	0.05	0.006	0.01	–	0.5	0.870	30	2.04	0	No
	Cesium-137		23,500,000	0.05	0.006	0.01	–	0.5	35.2	30	2.04	0	No
	Iridium-192		26,400,000	0.05	0.006	0.01	–	0.5	39.6	30	2.04	0	No
	Radium-226		87,400	0.05	0.006	0.01	–	0.5	0.131	30	2.04	0	No
	Curium-244		2,850	0.05	0.006	0.01	–	0.5	0.00427	30	2.04	0	No
	Californium-252		6,100	0.05	0.006	0.01	–	0.5	0.00915	30	2.04	0	No
Subtotal (impact plus high heat fire)	Cobalt-60	curies	–	–	–	–	–	–	56.4	30	2.04	0	No
	Strontium-90		–	–	–	–	–	–	9.57	30	2.04	0	No
	Cesium-137		–	–	–	–	–	–	388	30	2.04	0	No
	Iridium-192		–	–	–	–	–	–	436	30	2.04	0	No
	Radium-226		–	–	–	–	–	–	1.44	30	2.04	0	No
	Curium-244		–	–	–	–	–	–	0.0470	30	2.04	0	No
	Californium-252		–	–	–	–	–	–	0.101	30	2.04	0	No
Fire (smoldering)	Cobalt-60	curies	3,420,000	0.05	0.006	0.01	–	0.5	5.13	60	0.1	0	No
	Strontium-90		580,000	0.05	0.006	0.01	–	0.5	0.870	60	0.1	0	No
	Cesium-137		23,500,000	0.05	0.006	0.01	–	0.5	35.2	60	0.1	0	No
	Iridium-192		26,400,000	0.05	0.006	0.01	–	0.5	39.6	60	0.1	0	No
	Radium-226		87,400	0.05	0.006	0.01	–	0.5	0.131	60	0.1	0	No
	Curium-244		2,850	0.05	0.006	0.01	–	0.5	0.00427	60	0.1	0	No
	Californium-252		6,100	0.05	0.006	0.01	–	0.5	0.00915	60	0.1	0	No

Accident Phase	Nuclide	MAR (curies or grams)	MAR	Damage Ratio	Airborne Release Fraction	Respirable Fractions	Airborne Release Rate (per hour)	Leak Path Factor	Source Term (units of MAR)	Release Duration (minutes)	Plume Heat (mega-watts)	Release Height (meters)	Wake?
Identifier: MDAGEXP. **Scenario:** Explosion at a Pit at MDA G Expanded Operations Only													
Explosion	Americium-241	curies	352	0.02 [c]	0.005	0.3	–	1	0.0104	1	0	0	No
	Gadolinium-148	curies	0.466	1	0.005	0.3	–	1	0.000699	1	0	0	No
	Thorium-230	curies	2.67	1	0.005	0.3	–	1	0.00401	1	0	0	No
	Actinium-227	curies	0.0430	1	0.005	0.3	–	1	0.0000645	1	0	0	No
	Plutonium-238	curies	591	0.88 [c]	0.005	0.3	–	1	0.780	1	0	0	No
	Plutonium-239	curies	319	0.96 [c]	0.005	0.3	–	1	0.459	1	0	0	No
	Plutonium-240	curies	74.7	1	0.005	0.3	–	1	0.112	1	0	0	No
	Plutonium-241	curies	219	1	0.005	0.3	–	1	0.329	1	0	0	No
	Uranium-233	curies	1.03	0	0.005	0.3	–	1	0	1	0	0	No
	Uranium-234	curies	0.392	1	0.005	0.3	–	1	0.000588	1	0	0	No
	Uranium-238	curies	1.72	1	0.005	0.3	–	1	0.00258	1	0	0	No
Suspension	Americium-241	curies	352	0.02 [c]	–	1	0.000004	1	0.000659	1,440	0	0	No
	Gadolinium-148	curies	0.464	1	–	1	0.000004	1	0.0000445	1,440	0	0	No
	Thorium-230	curies	2.66	1	–	1	0.000004	1	0.0002550	1,440	0	0	No
	Actinium-227	curies	0.0428	1	–	1	0.000004	1	0.00000411	1,440	0	0	No
	Plutonium-238	curies	588	0.88 [c]	–	1	0.000004	1	0.0497	1,440	0	0	No
	Plutonium-239	curies	318	0.96 [c]	–	1	0.000004	1	0.0292	1,440	0	0	No
	Plutonium-240	curies	74.3	1	–	1	0.000004	1	0.00714	1,440	0	0	No
	Plutonium-241	curies	218	1	–	1	0.000004	1	0.0209	1,440	0	0	No
	Uranium-233	curies	1.03	0 [c]	–	1	0.000004	1	0	1,440	0	0	No
	Uranium-234	curies	0.390	1	–	1	0.000004	1	0.0000374	1,440	0	0	No
	Uranium-238	curies	1.71	1	–	1	0.000004	1	0.000164	1,440	0	0	No

MAR = material at risk, RANT = radioassay and nondestructive testing, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, DVRS = Decontamination and Volume Reduction System, SHEBA = Solution High-Energy Burst Assembly, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air filter, MDA = material disposal area.

[a] Plutonium Equivalent means the activity of plutonium-239 with the same radiological consequences.

[b] Weapons Grade Plutonium means a mix of plutonium isotopes representative of plutonium used in a nuclear weapon.

[c] Damage ratios less than 1 indicate that all or part of the inventory is in a waste form such as concrete that would not release respirable particles in this accident scenario.

Consequences are also expressed in terms of the likelihood of a latent cancer fatality (LCF) for the MEI and noninvolved worker and in terms of the number of additional LCFs for the offsite population. A conversion factor, 0.0006 LCFs (or number of LCFs) per rem (or person-rem), is used to convert rem (or person-rem) to the likelihood of an LCF (or number of LCFs); this factor is doubled for doses to an individual in excess of 20 rem.

D.3.2.1 No Action Alternative

The estimated consequences and annual risks of postulated accidents for the No Action Alternative are shown in **Tables D–4** through **D–6**. The maximum consequences and risks from facility accidents are chiefly a result of TA-54 operations (Radioactive Assay and Nondestructive Test [RANT], waste storage domes, DVRS).

The nearest public access to the CMR Building, Diamond Drive, approximately 170 feet (50 meters) from the CMR Building, is closer than the nearest site boundary to this facility. Doses were calculated for an individual at Diamond Drive during the duration of the high-efficiency particulate air (HEPA) filter fire at CMR. The same assumptions used to calculate dose to the MEI were applied to this individual. The dose at Diamond Drive would be 8.1 rem, more than 10 times the value indicated in Table D–4. The consequences and risks at this boundary location would also be 10 times the value indicated in Tables D–5 and D–6 for this scenario.

D.3.2.2 Reduced Operations Alternative

Accident impacts from the Reduced Operations Alternative are similar to those from the No Action Alternative, as given in Tables D–4 through D–6. Solution High-Energy Burst Assembly (SHEBA) operations at LANL would cease. Inspection of the tables shows that SHEBA operations are a small component of the facility impacts at LANL; its elimination would not significantly alter the overall risk profile from individual facility operations. All other impacts in the No Action Alternative tables are equally applicable for this alternative.

D.3.2.3 Expanded Operations Alternative

Accident impacts from the Expanded Operations Alternative, shown in **Tables D–7** through **D–9**, would be generally greater than those from the No Action Alternative. SHEBA operations at LANL would cease under the Expanded Operations Alternative; its relatively small impacts, have been eliminated from the tables. Additional or replacement risks from accident impacts would result from expanded waste management activities. Transuranic waste management at DVRS and the waste storage domes would be moved offsite or to a new facility, the Transuranic Waste Consolidation Facility, located in TA-50 or TA-63. The impacts to the public from this new facility would be less than those of the existing facilities because of the new location and because less material would be stored, the rest being moved offsite. Tables D–7 through D–9 reflect the present DVRS and waste storage domes operations because they would be active for most of the time period of interest and would bound the impacts of the new facility. Accident impacts for the new facility are described in Appendix H.

Table D–4 Radiological Accident Offsite Population Consequences for the No Action Alternative

Accident Scenario	MEI		Population to 50 Miles (80 kilometers)	
	Dose (rem)	Latent Cancer Fatality [a]	Dose (person-rem)	Latent Cancer Fatalities [b, c]
RANT Outdoor Container Storage Area Fire (TA-54-38)	71.5	0.0858	3,970	2 (2.38)
WETF Fire (TA-16-205)	5.91	0.00355	187	0 (0.112)
WCRR Outdoor Storage Area Fire (TA-50-69)	1.10	0.000660	265	0 (0.159)
Waste Storage Dome Fire (TA-54)	419	0.503	4,230	3 (2.54)
Onsite Transuranic Waste Fire Accident (TA-54)	186	0.223	5,720	3 (3.43)
Plutonium Facility Storage Container Release (TA-55-4)	2.50	0.00150	372	0 (0.223)
Plutonium Facility Ion Column Rupture (TA-55-4)	1.28	0.000768	131	0 (0.0786)
DVRS Operational Spill (TA-54)	19.6	0.0118	185	0 (0.111)
DVRS Building Fire and Spill Due to Forklift Collision (TA-54)	321	0.385	6,140	4 (3.68)
SHEBA Hydrogen Detonation (TA-18-168)	0.877	0.000526	69	0 (0.0414)
CMR HEPA Filter Fire (TA-3-29)	0.770	0.000464	200	0 (0.12)

MEI = maximally exposed individual, rem = roentgen equivalent man, RANT = Radioactive Assay and Nondestructive Test, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, DVRS = Decontamination and Volume Reduction System, SHEBA = Solution High-Energy Burst Assembly, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air filter.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Increased number of LCFs for the offsite population, assuming the accident occurs; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 404,900 (TA-16-205), 334,100 (TA-18-168), 271,600 (TA-21-155, and TA-21-209), 302,000 (TA-50-69), 343,100 (TA-54-38, DVRS, Domes), 301,900 (TA-55-4).

Table D–5 Radiological Accident Onsite Worker Consequences for the No Action Alternative

Accident Scenario	*Noninvolved Worker at 110 Yards (100 meters)*	
	Dose (rem)	*Latent Cancer Fatalities* [a]
RANT Outdoor Container Storage Area Fire (TA-54-38)	532	0.638
WETF Fire (TA-16-205)	8.92	0.00535
WCRR Outdoor Storage Area Fire (TA-50-69)	44.7	0.0536
Waste Storage Dome Fire (TA-54)	1,950	2.34 [b]
Onsite Transuranic Waste Fire Accident (TA-54)	761	0.913
Plutonium Facility Storage Container Release (TA-55-4)	35.8	0.0430
Plutonium Facility Ion Column Rupture (TA-55-4)	9.09	0.00545
DVRS Operational Spill (TA-54)	51.4	0.0617
DVRS Building Fire and Spill Due to Forklift Collision (TA-54)	888	1.07 [b]
SHEBA Hydrogen Detonation (TA-18-168)	15.4	0.00924
CMR HEPA Filter Fire (TA-3-29)	5.38	0.00323

rem = roentgen equivalent man, RANT = Radioactive Assay and Nondestructive Test, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, DVRS = Decontamination and Volume Reduction System, SHEBA = Solution High-Energy Burst Assembly, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air filter.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Based on a dose-risk-conversion factor of 0.0006 LCF per rem, the indicated dose yields a LCF value greater than 1.00 as shown. This means that it is likely that an individual exposed to the indicated dose would contract a fatal latent cancer in their lifetime. For calculation purposes, the actual value is shown here; however, since the exposed recipient is an individual, the equivalent tables in Chapter 5, Section 5.12 show an LCF of 1.00.

Table D–6 Radiological Accident Offsite Population and Worker Risks for the No Action Alternative

Accident Scenario	*Frequency (per year)*	*Onsite Worker*	*Offsite Population*	
		Noninvolved Worker at 110 Yards (100 meters) [a]	*MEI* [a]	*Population to 50 Miles (80 kilometers)* [b, c]
RANT Outdoor Container Storage Area Fire (TA-54-38)	0.01	0.00638	0.000858	0.0238
WETF Fire (TA-16-205)	1.1×10^{-5}	5.96×10^{-8}	3.95×10^{-8}	1.25×10^{-6}
WCRR Outdoor Storage Area Fire (TA-50-69)	0.0003	0.0000161	1.98×10^{-7}	0.0000477
Waste Storage Dome Fire (TA-54)	0.001	0.001	0.000503	0.00254
Onsite Transuranic Waste Fire Accident (TA-54)	0.001	0.000913	0.000223	0.00343
Plutonium Facility Storage Container Release (TA-55-4)	10^{-6}	4.3×10^{-8}	1.50×10^{-9}	2.23×10^{-7}
Plutonium Facility Ion Column Rupture (TA-55-4)	10^{-6}	5.45×10^{-9}	7.68×10^{-10}	7.86×10^{-8}
DVRS Operational Spill (TA-54)	0.02	0.00123	0.000235	0.00222
DVRS Building Fire and Spill Due to Forklift Collision (TA-54)	0.001	0.001	0.000385	0.00368
SHEBA Hydrogen Detonation (TA-18-168)	0.0054	0.0000499	2.84×10^{-6}	0.000224
CMR HEPA Filter Fire (TA-3-29)	0.01	0.0000323	4.64×10^{-6}	0.00120

MEI = maximally exposed individual, RANT = Radioactive Assay and Nondestructive Test, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, DVRS = Decontamination and Volume Reduction System, SHEBA = Solution High-Energy Burst Assembly, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air filter.

[a] Increased risk of an LCF to an individual per year.

[b] Increased number of LCFs in the offsite population per year; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 404,900 (TA-16-205), 334,100 (TA-18-168), 271,600 (TA-21-155, -209), 302,000 (TA-50-69), 343,100 (TA-54-38, DVRS, Domes), 301,900 (TA-55-4).

Table D–7 Radiological Accident Offsite Population Consequences for the Expanded Operations Alternative

Accident Scenario	MEI		Population to 50 Miles (80 kilometers)	
	Dose (rem)	Latent Cancer Fatality [a]	Dose (person-rem)	Latent Cancer Fatalities [b, c]
RANT Outdoor Container Storage Area Fire (TA-54-38)	71.5	0.0858	3,970	2.38
WETF Fire (TA-16-205)	5.91	0.00355	187	0.112
WCRR Outdoor Storage Area Fire (TA-50-69)	1.10	0.000660	265	0.159
Waste Storage Dome Fire (TA-54)	419	0.503	4,230	2.54
Onsite Transuranic Waste Fire Accident (TA-54)	186	0.223	5,720	3.43
Plutonium Facility Storage Container Release (TA-55-4)	2.50	0.00150	372	0.223
Plutonium Facility Ion Column Rupture (TA-55-4)	1.28	0.000768	131	0.0786
DVRS Operational Spill (TA-54)	19.6	0.0118	185	0.111
Explosion in a Pit at MDA G	55.2	0.0662	766	0.460
DVRS Building Fire and Spill Due to Forklift Collision (TA-54)	321	0.385	6,140	3.68
Fire at CMR Involving Sealed Sources (TA-3-29)	0.0987	0.0000592	11,600	6.96
CMR HEPA Filter Fire (TA-3-29)	0.774	0.000464	200	0.12

MEI = maximally exposed individual, rem = roentgen equivalent man, RANT = Radioactive Assay and Nondestructive Test, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, DVRS = Decontamination and Volume Reduction System, MDA = material disposal area, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air filter.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Increased number of LCFs for the offsite population, assuming the accident occurs; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 404,900 (TA-16-205), 271,600 (TA-21-155, -209), 302,000 (TA-50-69), 343,100 (TA-54-38, DVRS, Domes), 301,900 (TA-55-4).

Table D–8 Radiological Accident Onsite Worker Consequences for the Expanded Operations Alternative

Accident Scenario	Noninvolved Worker at 110 Yards (100 meters)	
	Dose (rem)	Latent Cancer Fatalities [a]
RANT Outdoor Container Storage Area Fire (TA-54-38)	532	0.638
WETF Fire (TA-16-205)	8.92	0.00535
WCRR Outdoor Storage Area Fire (TA-50-69)	44.7	0.0536
Waste Storage Dome Fire (TA-54)	1,950	2.34 [b]
Onsite Transuranic Waste Fire Accident (TA-54)	761	0.913
Plutonium Facility Storage Container Release (TA-55-4)	35.8	0.0430
Plutonium Facility Ion Column Rupture (TA-55-4)	9.09	0.00545
DVRS Operational Spill (TA-54)	51.4	0.0617
Explosion in a Pit at MDA G	405	0.486
DVRS Building Fire and Spill Due to Forklift Collision (TA-54)	888	1.07 [b]
Fire at CMR Involving Sealed Sources (TA-3-29)	1.21	0.000727
CMR HEPA Filter Fire (TA-3-)	5.38	0.00323

rem = roentgen equivalent man, RANT = Radioactive Assay and Nondestructive Test, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, DVRS = Decontamination and Volume Reduction System, MDA = material disposal area, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air filter.

[a] Increased risk of an LCF, assuming the accident occurs.

[b] Based on a dose-risk-conversion factor of 0.0006 LCF per rem, the indicated dose yields an LCF value greater than 1.00 as shown. This means that it is likely that an individual exposed to the indicated dose would contract a fatal latent cancer in their lifetime. For calculation purposes, the actual value is shown here; however, since the exposed recipient is an individual, the equivalent tables in Chapter 5, Section 5.12 show an LCF of 1.00.

Table D–9 Radiological Accident Offsite Population and Worker Risks for the Expanded Operations Alternative

Accident Scenario	*Frequency (per year)*	*Onsite Worker*	*Offsite Population*	
		Noninvolved Worker at 110 Yards (100 meters) [a]	*Maximally Exposed Individual* [a]	*Population to 50 Miles (80 kilometers)* [b, c]
RANT Outdoor Container Storage Area Fire (TA-54-38)	0.01	0.00638	0.000858	0.0238
WETF Fire (TA-16-205)	1.1×10^{-5}	5.96×10^{-8}	3.95×10^{-8}	1.25×10^{-6}
WCRR Outdoor Storage Area Fire (TA-50-69)	0.0003	0.0000161	1.98×10^{-7}	0.0000477
Waste Storage Dome Fire (TA-54)	0.001	0.001	0.000503	0.00254
Onsite Transuranic Waste Fire Accident (TA-54)	0.001	0.000913	0.000223	0.00343
Plutonium Facility Storage Container Release (TA-55-4)	10^{-6}	4.30×10^{-8}	1.50×10^{-9}	2.23×10^{-7}
Plutonium Facility Ion Column Rupture (TA-55-4)	10^{-6}	5.45×10^{-9}	7.68×10^{-10}	7.86×10^{-8}
DVRS Operational Spill (TA-54)	0.02	0.00123	0.000235	0.00222
Explosion in a Pit at MDA G	0.01	0.00486	0.000662	0.00460
DVRS Building Fire and Spill Due to Forklift Collision (TA-54)	0.001	0.001	0.000385	0.00368
Fire at CMR Involving Sealed Sources (TA-3-29)	0.00024	1.74×10^{-7}	1.42×10^{-8}	0.00167
CMR HEPA Filter Fire (TA-3-29)	0.01	0.0000323	4.64×10^{-6}	0.00120

RANT = Radioactive Assay and Nondestructive Test, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, DVRS = Decontamination and Volume Reduction System, MDA = Material Disposal Area, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air filter.

[a] Increased risk of an LCF to an individual per year.

[b] Increased number of LCFs for the offsite population per year; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 404,900 (TA-16-205), 334,100 (TA-18-168), 271,600 (TA-21-155, -209), 302,000 (TA-50-69), 343,100 (TA-54-38, DVRS, Domes), 301,900 (TA-55-4).

MDA cleanup is a component of the Expanded Operations Alternative. A number of scenarios were considered for this activity, and an explosion during cleanup operations that breaches the MDA enclosure and bypasses the HEPA filtration was chosen for analysis. MDA G, because of its relatively large inventory, was found to bound the accident impacts from MDA cleanup. The consequences and risks from this scenario are included in Tables D–7 through Table D–9. As with the No Action Alternative, TA-54 operations generally dominate the accident risks from Expanded Operations. Cleanup of MDA G, although not bounding, adds a component to this risk. Appendix I includes more details about MDA cleanup accident impacts.

Another component of the Expanded Operations Alternative (and not of the No Action Alternative) is the onsite storage of sealed sources. The important exposure pathways are different for some of the radionuclides that might be released from the sealed sources. Previously, sources received for management at LANL consisted chiefly of alpha emitters such as americium and plutonium, which are chiefly internal risks with dose to the body delivered over an extended time period. The nuclides associated with other sealed sources now being considered for management at LANL can be strong gamma emitters and thus may result in significant prompt external as well as internal exposure in the event of an accident.

A number of different radionuclides could be present in the sealed sources, as shown in Table D-3. The MARs shown there represent the maximum allowable inventory of each of the nuclides, were only that nuclide present. Each of the nuclides was separately analyzed and it was found that cobalt-60 would lead to the maximum exposure to the individuals closest to the release, such as the noninvolved worker, from exposure to source material as well as plume exposure; transuranics such as californium-252 would lead to the maximum exposure to individuals further from the release, such as the MEI at CMR, from plume exposure; and cesium-137 would lead to the maximum exposure to the general public from ground exposure from deposited material, internal exposure from ingestion of foodstuffs, and exposure to the release plume. The dose to an individual outside at Diamond Drive during the hypothetical fire at CMR involving sealed sources scenario would be 4.32 rem, 42 percent of which would be from external exposure to gamma radiation. Such a dose would result in an increased chance of a fatal cancer during the lifetime of the individual of 0.0026, or approximately 1 chance in 385.

The accident analysis for sealed sources conservatively assumes that the maximum allowable limit of one single radioisotope is present instead of a more realistic expected mix of several radioisotopes at lower activity levels. This assumption provides a bounding consequence in the event of a postulated accident that releases sealed source inventory or exposes gamma or neutron emitters so that direct radiation affects the dose to individuals close to the source. The analysis also assumes that the shipping containers that contain the source and the building within which the containers are stored both fail, resulting in external exposure and release of these radionuclides. Appendix J, Section J.3.3.2, contains further discussion of Sealed Source accident scenarios and risks.

D.3.3 Chemical Accident Impacts

This section provides information and data that supports the impacts of facility accidents presented in Chapter 5. It includes the estimated accident frequency of occurrence, scenarios, and materials released.

The chemicals of concern at LANL facilities and potential impacts under the No Action Reduced and Expanded Operations Alternatives are shown in **Table D–10**. These have been selected from a complete set of chemicals used onsite based on their quantities, chemical properties, and human health effects. The tables show the impact of each postulated chemical release and the applicable concentration guidelines. The first guideline is the concentration of a substance in air generally regarded as requiring action to prevent or mitigate exposures. The second guideline is the concentration above which severe irreversible health effects or fatality may occur. Emergency Response Planning Guideline (ERPG) -2 and -3 values published by the American Industrial Hygiene Association (AIHA 2005) are used in this analysis to represent those levels of impact, consistent with DOE emergency management hazards assessment and planning practices (DOE 2005a, DOE 1997).[1] ERPG-2 and ERPG-3 are defined in terms of the expected health impacts from a 1-hour exposure, as follows:

> *ERPG-2: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.*
>
> *ERPG-3: The maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.*

Table D–10 Chemical Accident Impacts

Chemical	Frequency (per year)	Quantity Released	ERPG-2 [a]		ERPG-3 [b]		Concentration	
			Value	Distance to Value (meters)	Value	Distance to Value (meters)	Noninvolved Worker at 100 Meters	MEI at Site Boundary
Selenium hexafluoride from waste cylinder storage at TA-54-216	0.0041	75 liters (20 gallons)	0.6 ppm [c]	2,800	5 ppm [c]	880	143 ppm	12 ppm at 491 meters
Sulfur dioxide from waste cylinder storage at TA-54-216	0.00051	300 pounds (136 kilograms)	3 ppm	1,650	15 ppm	690	312 ppm	27.2 ppm at 491 meters
Chlorine gas released outside of Plutonium Facility (TA-55-4)	0.063	150 pounds (68 kilograms)	3 ppm	1,080	20 ppm	380	165 ppm	3.38 ppm at 1,016 meters
Helium at TA-55-41	0.063	9,230,000 cubic feet (261,366 cubic meters) (at STP)	280,000 ppm [c]	197	500,000 ppm [c]	139	greater than ERPG-3	10,300 ppm at 1,048 meters

ERPG = Emergency Response Planning Guideline, MEI = maximally exposed individual, TA = technical area, ppm = parts per million, STP = standard temperature and pressure, TEEL = Temporary Emergency Exposure Limits.
[a] ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective action (DOE 2004a).
[b] ERPG-3 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects (DOE 2004a).
[c] The TEEL value is used. ERPGs have not been issued for this substance.

[1] Beginning with the recent issuance of DOE Order 151.1C (November 2005) Acute Exposure Guideline Levels published by the U.S. Environmental Protection Agency (EPA) are specified as the chemical impact criteria of first choice, and incorporation of those values into hazards assessments and emergency plans is beginning throughout DOE. Acute Exposure Guideline Levels are defined in terms of several different exposure times ranging from 10 minutes to 8 hours. In general, the Acute Exposure Guideline Levels-2 and -3 values for a 60-minute exposure are about the same as the ERPGs used in this analysis.

ERPGs are used throughout industry and government to assess chemical hazards and plan for emergencies. However, ERPGs have been issued for fewer than 120 chemicals as of 2005. To provide its sites and facilities with impact criteria for other chemicals, DOE commissions the development of alternative values, termed Temporary Emergency Exposure Limits (TEELs). As of late 2005, TEEL values have been issued for nearly 3,000 chemicals (DOE 2005b). The TEEL levels of TEEL-2 and TEEL-3 are defined in the same words as the corresponding ERPGs, but without reference to any duration of exposure. When no ERPGs have been published for a substance, the TEEL-2 and -3 values are used in this analysis to represent the ERPG-2 and ERPG-3 levels of health impact.

D.3.3.1 No Action Alternative

The chemicals of concern at LANL facilities under the No Action Alternative are shown in Table D–10. Selenium hexafluoride, sulfur dioxide, and chlorine are all toxic gases which can, at elevated levels, cause respiratory dysfunction, among other health effects. Helium is an asphyxiant that can cause health effects by displacing breathable oxygen.

Table D–10 shows the concentrations of each chemical, if released, at specified distances. The inventory of each chemical is assumed to be released from a break in a line over a 10-minute interval. The cause of the break could be mechanical failure, corrosion, mechanical impact, or natural phenomena. The noninvolved worker, if directly downwind from the release and unable to take evasive action, would be exposed to levels in excess of ERPG-3 for these releases. Under the same circumstances, the MEI located at the LANL and San Ildefonso Pueblo boundary would be exposed to selenium hexafluoride and sulfur dioxide in excess of ERPG-3 levels.

D.3.3.2 Reduced Operations Alternative

The chemicals of concern that could be released in a facility accident are the same for the Reduced Operations Alternative as for the No Action Alternative. None of the chemicals identified for the latter are eliminated in this alternative. The information in Table D–10, then, is applicable to the Reduced Operations Alternative.

D.3.3.3 Expanded Operations Alternative

The chemicals of concern that could be released in a facility accident for the No Action Alternative apply equally to the Expanded Operations Alternative. In addition, MDA cleanup is a component of the Expanded Operations Alternative for which the potential for accidental releases of toxic chemicals exists. A fire during excavation which breaches the MDA enclosure and bypasses the HEPA filtration was chosen as a severe scenario. There is a great deal of uncertainty as to how much and which chemicals were disposed of in the MDAs; the MDA closest to the public (and thus with the potential for the greatest impact on the public), MDA-B, was chosen to bound the chemical accident impacts for MDA cleanup. Two chemicals, sulfur dioxide (a gas) and beryllium (assumed in powder form), were chosen, based on their restrictive ERPG values, to bound the impacts of an extensive list of possible chemicals disposed of in the MDAs. **Table D–11** shows that both of these chemicals, if present in MDA-B at the quantities assumed, would dissipate to below ERPG-3 levels very close to the release. Appendix I includes more details about MDA cleanup chemical accident impacts.

Table D–11 Chemical Accident Impacts for the Expanded Operations Alternative

Chemical	Frequency (per year)	Quantity Released	ERPG-2 [a]		ERPG-3 [b]		Concentration	
			Value	Distance to Value (meters)	Value	Distance to Value (meters)	Noninvolved Worker at 100 Meters	MEI at Site Boundary
Selenium hexafluoride from waste cylinder storage at TA-54-216	0.0041	75 liters (20 gallons)	0.6 ppm [c]	2,800	5 ppm [c]	880	143 ppm	12 ppm at 491 meters
Sulfur dioxide from waste cylinder storage at TA-54-216	0.00051	300 pounds (160 kilograms)	3 ppm	1,650	15 ppm	690	312 ppm	27.2 ppm at 491 meters
Chlorine gas released outside of Plutonium Facility (TA-55-4)	0.063	150 pounds (68 kilograms)	3 ppm	1,080	20 ppm	380	165 ppm	3.38 ppm at 1,016 meters
Helium at TA-55-41	0.063	9,230,000 cubic feet (261,366 cubic meters) (at STP)	280,000 ppm [c]	197	500,000 ppm	139	> ERPG-3	10,300 ppm at 1,048 meters
Sulfur dioxide at MDA B	Unknown	1 pound (0.45 kilogram)	3 ppm	83	15 ppm	34	2.1 ppm	9.2 ppm at 45 meters
Beryllium powder at MDA B	Unknown	22 pounds [d] (10 kilograms)	.025 mg/cu m	23	0.1 mg/cu m	9	0.0025 mg/cu m	0.0088 mg/cu m at 45 meters

ERPG = Emergency Response Planning Guideline, MEI = maximally exposed individual, TA = technical area, ppm = parts per million, STP = standard temperature and pressure, MDA = material disposal area, mg/cu m = milligrams per cubic meter.

[a] ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective action (DOE 2004a).

[b] ERPG-3 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects (DOE 2004a).

[c] The TEEL value is used. ERPGs have not been issued for this substance.

[d] This quantity represents the total material at risk. A fraction (6×10^{-5}) of this solid would be released as respirable particles in the hypothesized scenario.

D.4 Site-wide Seismic Impacts

Two site-wide seismic events, denoted as Seismic 1 and Seismic 2, were postulated to estimate the effects of potential radiological and chemical releases. Seismic 1 is nominally represented by a Performance Category-2 (PC-2) earthquake. Such an event is characterized by a return period of 1,000 years (annual probability of exceedance of 1×10^{-3}), with a peak horizontal ground acceleration of 0.22 g (gravitational acceleration).[2] Seismic 2 is nominally represented by a PC-3 earthquake, with a return period of 2,000 years (annual probability of exceedance of 5×10^{-4}) and a peak horizontal ground acceleration of 0.31 g (Cuesta 2004). Were such a site-wide seismic event to occur, simultaneous radiological and chemical releases from multiple locations could result. The evolution for choosing these scenarios is described in Table D–1. Most of these scenarios evolved from those analyzed in the *1999 SWEIS*. Revisions to the seismic releases in

[2] A g, standing for the acceleration due to gravity of 32 feet per second per second (9.8 meters per second per second) is a standard measure of ground movement associated with seismic events.

that earlier document (called Site releases there) were based on information available subsequent to the writing of the *1999 SWEIS*. New information was reviewed and significant scenarios added as appropriate. An example is the addition of the Safe Secure Transport Facility (TA-55-355). That facility houses material that was at TA-18 at the time of the *1999 SWEIS*. The current document considers the new location and storage design, while deleting the TA-18 buildings that are no longer operating.

The health effects calculated for these two postulated seismic events should be considered within the context of nonradiological human health impacts expected. These seismic events would cause widespread failures of nonnuclear LANL structures and structures outside of LANL. A much larger number of fatalities and injuries from structure collapse would be expected for these seismic events.

D.4.1 Source Term Data

Table D–12 shows the source term data used in the calculation of impacts to workers and the public that could result from a site-wide earthquake. A single table is presented for the two earthquake scenarios (Seismic 1 and 2); the scenario corresponding to each release is indicated under the facility name.

D.4.2 No Action Alternative Impacts

D.4.2.1 Site-wide Seismic 1 – Radiological Impacts

Site-wide Seismic 1 is associated with seismic events up to approximately PC-2 in severity. **Tables D–13** and **D–14** show the potential consequences (dose and probability of an LCF) should such an earthquake occur under the No Action Alternative. **Table D–15** shows the health risk (frequency multiplied by the LCF consequence) per year of operation. The largest risk from this event is from potential CMR releases.

If a Seismic 1 event were to occur, all of the releases shown in Table D–15 could emanate simultaneously. Accordingly, the sum of the health risk from each facility to the general population is indicated at the bottom of that table. This sum can be thought of as the overall health risk to the general population from a Seismic 1 event. The overall risk is seen to be approximately 0.005 per year, that is, a mean of one cancer fatality in the entire general population (out to 50 miles [80 kilometers] from each release) every 200 years of LANL operation.

Risks to individuals, on the other hand, cannot be summed because a single individual would not likely be exposed to multiple facility releases. Instead, only releases upwind from the individual's location would result in exposure. Table D–15, therefore, indicates the maximum health risk to the MEI from a release at any facility.

Table D–12 Site-wide Earthquake Source Term Data

Accident Phase	*Nuclide*	*MAR (curies or grams)*	*MAR*	*Damage Ratio*	*Airborne Release Fraction*	*Respirable Fractions*	*Airborne Release Rate (per hour)*	*Leak Path Factor*	*Source Term (in units of MAR)*	*Release Duration (minutes)*	*Plume Heat (mega-watts)*	*Release Height (meters)*	*Wake?*
Seismic													
Identifier: CMR08. **Facility Name:** TA-3-29 (CMR Building) *Seismic 1 and 2*													
Initial	Plutonium Equivalent	curies	1,240	1	0.01	0.5	–	1	6.19	10	0	0	No
Suspension			1,230	1	0	1	0.000004	1	0.118	1,440	0	0	No
Identifier: SIT02. **Facility Name:** TA-16-205 (WETF) *Seismic 2*													
Tritium release	Tritiated Water	grams	1,000	1	1.00	1	–	1	1,000	10	0	0	No
Identifier: SIT08 **Facility Name:** TA-18-168 (SHEBA) *Seismic 1 and 2*													
Metal	Plutonium Equivalent	grams	9,020	1	0.00	1	–	1	0	10	0	0	No
Ceramic			924	1	0.00006	1	–	1	0.0554	10	0	0	No
Liquid			9.00	1	0.0002	0.8	–	1	0.00144	10	0	0	No
Powder			0.06	1	0.002	0.3	–	1	0.000036	10	0	0	No
Gas			0	1	1.00	1	–	1	0	10	0	0	No
Total													
Initial	Plutonium Equivalent	grams	–	–	–	–	–	–	0.0569	10	0	0	No
Suspension			0.0599	1	0.00	1	0.000004	1	0.00000575	1,440	0	0	No
Identifier: SIT09. **Facility Name:** TA-21-155 (TSTA) *Seismic 1 and 2*													
Tritium release	Tritiated Water	grams	0.1	1	1.00	1	–	1	0.1	10	0	0	No
Identifier: SIT10. **Facility Name:** TA-21-209 (TSFF) *Seismic 1 and 2*													
Tritium release	Tritiated Water	grams	0.88	1	1.00	1	–	1	0.88	10	0	0	No
Identifier: SIT11. **Facility Name:** TA-50-1 (RLWTF) *Seismic 1 and 2*													
Initial	Plutonium-238	grams	–	–	–	–	–	–	0.000058	10	0	0	No
	Plutonium-239		–	–	–	–	–	–	0.27	10	0	0	No
	Americium-241		–	–	–	–	–	–	0.005	10	0	0	No
Suspension	Plutonium-238		–	–	–	–	–	–	0.00013	1,440	0	0	No
	Plutonium-239		–	–	–	–	–	–	5.85	1,440	0	0	No
	Americium-241		–	–	–	–	–	–	0.11	1,440	0	0	No

Accident Phase	*Nuclide*	*MAR (curies or grams)*	*MAR*	*Damage Ratio*	*Airborne Release Fraction*	*Respirable Fractions*	*Airborne Release Rate (per hour)*	*Leak Path Factor*	*Source Term (in units of MAR)*	*Release Duration (minutes)*	*Plume Heat (mega-watts)*	*Release Height (meters)*	*Wake?*
Identifier: SIT13. **Facility Name:** TA-50-69 (WCRR) *Seismic 2*													
Initial	Plutonium Equivalent	curies	–	–	–	–	–	–	0.39	10	0	0	No
Suspension			–	–	–	–	–	–	0.037	1,440	0	0	No
Identifier: SIT14. **Facility Name:** TA-54-38 (RANT) *Seismic 1 and 2*													
Initial	Plutonium Equivalent	curies	1,860	1	0.001	1	–	1	1.86	10	0	0	No
Suspension			1,860	1	–	1	0.000004	1	0.178	1,440	0	0	No
Identifier: SIT15. **Facility Name:** TA-55-4 (Plutonium Facility) *Seismic 2*													
Initial	Plutonium-238	grams	–	–	–	–	–	–	0.0129	10	0	0	Yes
	Plutonium-239		–	–	–	–	–	–	4.84	10	0	0	Yes
	Plutonium-240		–	–	–	–	–	–	0.323	10	0	0	Yes
	Plutonium-241		–	–	–	–	–	–	0.0251	10	0	0	Yes
	Plutonium-242		–	–	–	–	–	–	0.179	10	0	0	Yes
	Americium-241		–	–	–	–	–	–	0.0038	10	0	0	Yes
	Highly-enriched Uranium		–	–	–	–	–	–	0.241	10	0	0	Yes
Identifier: SIT19. **Facility Name:** TA-55-355 (SST) *Seismic 2*													
Free fall spill	Plutonium-239	grams	50,000	0.093	0.002	0.3	–	1	2.80	10	0	0	Yes
Powder impacted by object			50,000	0.047	0.01	0.2	–	1	4.67	10	0	0	Yes
Identifier: DOMEP. **Facility Name:** Waste storage domes (for population [a]) *Seismic 2*													
Combustibles													o
Drums	Plutonium Equivalent	curies	25,800	0.333	0.001	0.3		1	2.58	10	0	0	No
Overpacks			11,300	0.167	0.001	0.3		1	0.566	10	0	0	No
Suspension			10,500	1	–	1	0.000004	1	1.01	1,440	0	0	N
Noncombustibles													
Drums	Plutonium Equivalent	curies	70,400	0.333	0.000849	0.3		1	5.98	10	0	0	No
Overpacks			30,900	0.167	0.000762	0.3		1	1.18	10	0	0	No
Suspension			23,800	1	–	1	0.000004	1	2.29	1,440	0	0	No

Accident Phase	Nuclide	MAR (curies or grams)	MAR	Damage Ratio	Airborne Release Fraction	Respirable Fractions	Airborne Release Rate (per hour)	Leak Path Factor	Source Term (in units of MAR)	Release Duration (minutes)	Plume Heat (mega-watts)	Release Height (meters)	Wake?
Total													
Initial	Plutonium Equivalent	curies	–	–	–	–	–	–	10.3	10	0	0	No
Suspension			–	–	–	–	–	–	3.30	1,440	0	0	No
Identifier: DOMEM **Facility Name:** Waste storage domes (for MEI and Noninvolved Worker [a]) *Seismic 2*													
Combustibles											0	0	No
Drums	Plutonium Equivalent	curies	15,900	0.333	0.001	0.3	–	1	1.59	10	0	0	No
Overpacks			6,960	0.167	0.001	0.3	–	1	0.348	10	0	0	No
Suspension			6,440	1	–	1	0.000004	1	0.619	1,440	0	0	No
Noncombustibles													
Drums	Plutonium Equivalent	curies	44,100	0.333	0.000849	0.3	–	1	3.75	10	0	0	No
Overpacks			19,400	0.167	0.000762	0.3	–	1	0.737	10	0	0	No
Suspension			14,900	1	–	1	0.000004	1	1.43	1,440	0	0	No
Total													
Initial	Plutonium Equivalent	curies	–	–	–	–	–	–	6.42	10	0	0	No
Suspension			–	–	–	–	–	–	2.05	1,440	0	0	No
Identifier: SIT16. **Facility Name:** TA-55-185 *Seismic 1 and 2*													
Initial	Plutonium Equivalent	grams	48,900	1	0.00021	1	–	1	10.3	10	0	0	No
Suspension			48,900	1	–	1	0.000004	1	4.69	1,440	0	0	No
Identifier: DVRS08. **Facility Name:** DVRS (PC-2) *Seismic 1*													
PC-2 Seismic Event	Plutonium Equivalent	curies	900	1	0.001	0.1	–	1	0.09	1,440	0	0	No
Identifier: DVRS12. **Facility Name:** DVRS (PC-3) *Seismic 2*													
PC-3 Seismic Event	Plutonium Equivalent	curies	1,100	1	0.001	1	–	1	1.10	1,440	0	0	No

MAR = material at risk, TA = technical area, CMR = Chemistry and Metallurgy Research Building, WETF = Weapons Engineering Tritium Facility, SHEBA = Solution High-Energy Burst Assembly, TSTA = Tritium Systems Test Assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, RANT = radioassay and nondestructive testing, SST = safe secure trailer, MEI = maximally exposed individual, DVRS = Decontamination and Volume Reduction System, PC = performance category.

[a] Separate analyses were performed for the population and for the MEI and noninvolved worker because releases from all of the doses would affect the population whereas an individual would be affected by only a subset of doses that are close to each other.

Table D–13 Site-wide Seismic 1 Radiological Accident Offsite Population Consequences for the No Action Alternative

Facility Impacted by Seismic 1 Event	*MEI*		*Population to 50 Miles (80 kilometers)*	
	Dose (rem)	*Latent Cancer Fatality* [a]	*Dose (person-rem)*	*Latent Cancer Fatalities* [b, c]
TA-3-29 (CMR)	62.0	0.0744	6,080	3.65
TA-18-168 (SHEBA)	0.0301	0.0000181	0.770	0.000462
TA-21-155 (TSTA)	0.00146	8.76×10^{-7}	0.0492	0.0000295
TA-21-209 (TSFF)	0.0125	7.50×10^{-6}	0.433	0.000260
TA-50-1 (RLWTF)	3.02	0.00181	515	0.309
TA-54-38 (RANT)	64.2	0.0770	1,120	0.672
TA-55-185 (Storage Shed)	5.98	0.00359	589	0.353
TA-54-412 DVRS (PC-2 Seismic)	2.76	0.00166	49.1	0.0295
	Max 64.2	Max 0.0770	Sum 8,354	Sum 5.01

MEI = maximally exposed individual, rem = roentgen equivalent man, TA = technical area, CMR = Chemistry and Metallurgy Research Building, SHEBA = Solution High-Energy Burst Assembly, TSTA =Tritium Systems Test Assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, RANT = Radioactive Assay and Nondestructive Test, DVRS = Decontamination and Volume Reduction System, PC = performance category.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Increased number of LCFs for the offsite population, assuming the accident occurs; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 334,100 (TA-18-168), 271,600 (TA-21-155, -209), 302,000 (TA-50-1), 343,100 (TA-54-38, DVRS).

Table D–14 Site-wide Seismic 1 Radiological Accident Onsite Worker Consequences for the No Action Alternative

Facility Impacted by Seismic 1 Event	*Noninvolved Worker at 110 Yards (100 meters)*	
	Dose (rem)	*Latent Cancer Fatality* [a]
TA-3-29 (CMR)	1,940	2.33 [b]
TA-18-168 (SHEBA)	1.06	0.000636
TA-21-155 (TSTA)	0.0111	6.66×10^{-6}
TA-21-209 (TSFF)	0.0974	0.0000584
TA-50-1 (RLWTF)	121	0.145
TA-54-38 (RANT)	576	0.691
TA-55-185 (Storage Shed)	239	0.287
TA-54-412 DVRS (PC-2 Seismic)	10.1	0.00606

rem = roentgen equivalent man, TA = technical area, CMR = Chemistry and Metallurgy Research Building, SHEBA = Solution High-Energy Burst Assembly, TSTA =Tritium Systems Test Assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, RANT = Radioactive Assay and Nondestructive Test, DVRS = Decontamination and Volume Reduction System, PC = performance category.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Based on a dose-risk-conversion factor of 0.0006 LCF per rem, the indicated dose yields an LCF value greater than 1.00 as shown. This means that it is likely that an individual exposed to the indicated dose would contract a fatal latent cancer in their lifetime. For calculation purposes, the actual value is shown here; however, since the exposed recipient is an individual, the equivalent tables in Chapter 5, Section 5.12 show an LCF of 1.00.

Table D–15 Site-wide Seismic 1 Radiological Accident Offsite Population and Worker Risks for the No Action Alternative

Facility Impacted by Seismic 1 Event	*Frequency (per year)*	*Onsite Worker*	*Offsite Population*	
		Noninvolved Worker at 110 Yards (100 meters) [a]	*MEI* [a]	*Population to 50 Miles (80 kilometers)* [b, c]
TA-3-29 (CMR)	0.001	0.001	0.0000744	0.00365
TA-18-168 (SHEBA)	0.001	6.36×10^{-7}	1.81×10^{-8}	4.62×10^{-7}
TA-21-155 (TSTA)	0.001	6.66×10^{-9}	8.76×10^{-10}	2.95×10^{-8}
TA-21-209 (TSFF)	0.001	5.84×10^{-8}	7.50×10^{-9}	2.60×10^{-7}
TA-50-1 (RLWTF)	0.001	0.000145	1.81×10^{-6}	0.000309
TA-54-38 (RANT)	0.001	0.000691	0.0000770	0.000672
TA-55-185 (Storage Shed)	0.001	0.000287	3.59×10^{-6}	0.000353
TA-54-412 DVRS (PC-2 Seismic)	0.001	6.06×10^{-6}	1.66×10^{-6}	0.0000295
		Max 0.001	Max 0.0000770	Sum 0.00501

MEI = maximally exposed individual, TA = technical area, CMR = Chemistry and Metallurgy Research Building, SHEBA = Solution High-Energy Burst Assembly, TSTA =Tritium Systems Test Assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, RANT = Radioactive Assay and Nondestructive Test, DVRS = Decontamination and Volume Reduction System, PC = performance category.

[a] Increased risk of an LCF to an individual per year.

[b] Increased number of LCFs for the offsite population per year; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 334,100 (TA-18-168), 271,600 (TA-21-155, -209), 302,000 (TA-50-1), 343,100 (TA-54-38, DVRS).

There is potential for an individual at publicly accessible Diamond Drive, approximately 55 yards (50 meters) from CMR, to receive an exposure from that facility in excess of the MEI exposure. MACCS2 dispersion calculations, the underlying basis for this result, are generally considered to be conservatively high within 330 feet (100 meters) of a release. The calculated dose at Diamond Drive is 6,400 rem, 100 times the CMR MEI dose indicated in Table D–13. If an individual were at the Diamond Drive location for the duration of the CMR release, he would likely contract a fatal cancer during his lifetime.

D.4.2.2 Site-wide Seismic 2 – Radiological Impacts

Site-wide Seismic 2 is associated with events up to approximately PC-3 in severity. **Tables D–16** and **D–17** show the potential consequences (dose and probability of an LCF) should such an earthquake occur for the No Action Alternative. **Table D–18** shows the health risk (frequency multiplied by the LCF consequence) per year of operation. All of the releases from the Seismic 1 event would, of course, be released during this event as well. The waste storage domes would be among the facilities from which there would be no releases during a Seismic 1 event but which would have releases in the event of this larger Seismic 2 event. This facility and CMR represent the major sources of risk for this event. The overall health risk to the general population from this event is seen to be approximately 0.005 per year, that is, a mean of one LCF in the entire general population (out to 50 miles [80 kilometers] from each release) every 200 years of LANL operation. Therefore, the risk from a Seismic 1 or 2 event is roughly equivalent.

Table D–16 Site-wide Seismic 2 Radiological Accident Offsite Population Consequences for the No Action Alternative

Facility Impacted by Seismic 2 Event	MEI		Population to 50 Miles (80 kilometers)	
	Dose (rem)	Latent Cancer Fatality [a]	Dose (person-rem)	Latent Cancer Fatality [b, c]
TA-3-29 (CMR)	62.0	0.0744	6,080	3.65
TA-16-205 (WETF)	6.43	0.00386	159	0.0952
TA-18-168 (SHEBA)	0.0301	0.0000181	0.770	0.000462
TA-21-155 (TSTA)	0.00146	8.76×10^{-7}	0.0492	0.0000295
TA-21-209 (TSFF)	0.0125	7.50×10^{-6}	0.433	0.000260
TA-50-1 (RLWTF)	3.02	0.00181	515	0.309
TA-50-69 (WCRR)	2.84	0.00170	237	0.142
TA-54-38 (RANT)	64.2	0.0770	1,120	0.672
TA-55-4 (Plutonium Facility)	4.21	0.00253	403	0.242
TA-55-185 (Storage Shed)	5.98	0.00359	589	0.353
TA-54-412 DVRS (PC-3 Seismic)	33.7	0.0404	601	0.361
Waste storage domes (TA-54)	462	0.554	7,430	4.46
TA-55-355 (SST)	3.94	0.00236	294	0.176
	Max 462	0.554	Sum 17,429	10.46

MEI = maximally exposed individual, rem = roentgen equivalent man, TA = technical area, CMR = Chemistry and Metallurgy Research Building, WETF = Weapons Engineering Tritium Facility, SHEBA = Solution High-Energy Burst Assembly, TSTA = Tritium Systems Test Assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, RANT = Radioactive Assay and Nondestructive Test, DVRS = Decontamination and Volume Reduction System, PC = performance category, SST = safe secure trailer.

[a] Increased risk of an LCF to an individual per year.

[b] Increased number of LCFs for the offsite population per year; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 404,900 (TA-16-205), 334,100 (TA-18-168), 271,600 (TA-21-155, -209), 302,000 (TA-50-1, -69), 343,100 (TA-54-38, DVRS, Domes), 301,900 (TA-55-4, -185, -355).

The consequence to an individual at publicly accessible Diamond Drive from a Seismic 2 release from CMR could exceed that from the nearest site boundary. This consequence is the same as for the Seismic 1 event; the effects of the CMR release are discussed in detail under that heading.

D.4.2.3 Site-wide Seismic 1 – Chemical Impacts

The facilities and chemicals of concern under site-wide Seismic 1 conditions are shown in **Table D–19**. There are numerous chemicals in small quantities onsite that could be released under these conditions. The listed chemicals have been selected from a complete set of chemicals used onsite based on their larger quantities, chemical properties, and human health effects. Table D–19 shows the ERPG concentration values for which concentrations in excess of these could have harmful health or life-threatening implications as defined in the table's footnotes. Hydrogen cyanide, phosgene, and formaldehyde are toxic gases which can, at elevated levels, cause respiratory or cardiovascular (in the case of hydrogen cyanide) dysfunction. The hypothetical MEI could be exposed to formaldehyde concentrations in excess of ERPG-3 values in the event of such an earthquake, depending on the meteorological conditions at the time. This high exposure is a result of the proximity of TA-43-1 to the site border with the Los Alamos townsite. The noninvolved worker could be exposed to phosgene or formaldehyde in excess of ERPG-3 values if located directly downwind of the releases and unable to take evasive action.

Table D–17 Site-wide Seismic 2 Radiological Accident Onsite Worker Consequences for the No Action Alternative

Facility Impacted by Seismic 2 Event	*Noninvolved Worker at 110 Yards (100 meters)*	
	Dose (rem)	*LCF* [a]
TA-3-29 (CMR)	1,940	2.33 [b]
TA-16-205 (WETF)	5.86	0.00352
TA-18-168 (SHEBA)	1.06	0.000636
TA-21-155 (TSTA)	0.0111	6.66×10^{-6}
TA-21-209 (TSFF)	0.0974	0.0000584
TA-50-1 (RLWTF)	121	0.145
TA-50-69 (WCRR)	129	0.155
TA-54-38 (RANT)	576	0.691
TA-55-4 (Plutonium Facility)	47.9	0.0575
TA-55-185 (Storage Shed)	239	0.287
DVRS (PC-3 Seismic)	123	0.148
Waste storage domes (TA-54)	2,150	2.58 [b]
TA-55-355 (SST)	129	0.155

rem = roentgen equivalent man, LCF = latent cancer fatality, TA = technical area, CMR = Chemistry and Metallurgy Research Building, WETF = Weapons Engineering Tritium Facility, SHEBA = Solution High-Energy Burst Assembly, TSTA = Tritium Systems Test Assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, RANT = Radioactive Assay and Nondestructive Test, DVRS = Decontamination and Volume Reduction System, SST = safe secure trailer.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Based on a dose-risk-conversion factor of 0.0006 LCF per rem, the indicated dose yields an LCF value greater than 1.00 as shown. This means that it is likely that an individual exposed to the indicated dose would contract a fatal latent cancer in their lifetime. For calculation purposes, the actual value is shown here; however, since the exposed recipient is an individual, the equivalent tables in Chapter 5, Section 5.12 show an LCF of 1.00.

Table D–19 shows the concentration of each chemical, if it were released, at specified distances. The estimated frequency of this seismic event is shown in the table.

D.4.2.4 Site-wide Seismic 2 – Chemical Impacts

The facilities and chemicals of concern under site-wide Seismic 2 conditions are shown in **Table D–20**. There are numerous chemicals in small quantities onsite that could be released under these conditions. The listed chemicals have been selected from a complete set of chemicals used onsite based on their larger quantities, chemical properties, and human health effects. The table shows the ERPG concentration values for which concentrations in excess could have harmful health or life-threatening implications, as defined in the table's footnotes.

Table D–18 Site-wide Seismic 2 Radiological Accident Offsite Population and Worker Risks for the No Action Alternative

Facility Impacted by Seismic 2 Event	Frequency (per year)	Onsite Worker: Noninvolved Worker at 110 Yards (100 meters) [a]	Offsite Population: MEI [a]	Offsite Population: Population to 50 Miles (80 kilometers) [b, c]
TA-3-29 (CMR)	0.0005	0.0005	0.0000372	0.00182
TA-16-205 (WETF)	0.0005	1.76×10^{-6}	1.93×10^{-6}	0.0000476
TA-18-168 (SHEBA)	0.0005	3.18×10^{-7}	9.03×10^{-9}	2.31×10^{-7}
TA-21-155 (TSTA)	0.0005	3.33×10^{-9}	4.38×10^{-10}	1.48×10^{-8}
TA-21-209 (TSFF)	0.0005	2.92×10^{-8}	3.75×10^{-9}	1.30×10^{-7}
TA-50-1 (RLWTF)	0.0005	0.0000726	9.06×10^{-7}	0.000155
TA-50-69 (WCRR)	0.0005	0.0000774	8.52×10^{-7}	0.0000711
TA-54-38 (RANT)	0.0005	0.000346	0.0000385	0.000336
TA-55-4 (Plutonium Facility)	0.0005	0.0000287	1.26×10^{-6}	0.000121
TA-55-185 (Storage Shed)	0.0005	0.000143	1.79×10^{-6}	0.000177
DVRS (PC-3 Seismic)	0.0005	0.0000738	0.0000202	0.000180
Waste storage domes (TA-54)	0.0005	0.0005	0.000277	0.00223
TA-55-355 (SST)	0.0005	0.0000774	1.18×10^{-6}	0.0000882
		Max 0.0005	Max 0.000277	Sum 0.00523

MEI = maximally exposed individual, TA = technical area, CMR = Chemistry and Metallurgy Research Building, WETF = Weapons Engineering Tritium Facility, SHEBA = Solution High-Energy Burst Assembly, TSTA =Tritium Systems Test Assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, RANT = Radioactive Assay and Nondestructive Test, DVRS = Decontamination and Volume Reduction System, PC = performance category, SST = safe secure trailer.

[a] Increased risk of an LCF to an individual per year.

[b] Increased number of LCFs for the offsite population per year; value in parentheses is the calculated result.

[c] Offsite population size out to a 50-mile (80-kilometer) radius is approximately 297,000 (TA-3-29), 404,900 (TA-16-205), 334,100 (TA-18-168), 271,600 (TA-21-155, -209), 302,000 (TA-50-1, -69), 343,100 (TA-54-38, DVRS, Domes), 301,900 (TA-55-4, -185, -355).

Table D–19 Chemical Accident Impacts Under Seismic 1 Conditions

Chemical	Frequency (per year)	Quantity Released	ERPG-2 [a] Value	ERPG-2 [a] Distance to Value (meters)	ERPG-3 [b] Value	ERPG-3 [b] Distance to Value (meters)	Concentration: Noninvolved Worker at 100 Meters	Concentration: MEI at Site Boundary
Hydrogen Cyanide at TA-3-66 (Sigma Complex)	0.001	13.5 pounds (6 kilograms)	10 ppm	140	25 ppm	86	18.6 ppm	0.252 ppm at 924 meters
Phosgene at TA-9-21	0.001	1 pound (0.45 kilogram)	0.2 ppm	280	1 ppm	120	1.38 ppm	0.0252 ppm at 823 meters
Formaldehyde at TA-43-1 (Bioscience Facilities)	0.001	14.1 liters (3.7 gallons)	10 ppm	180	25 ppm	110	31.3 ppm	Exceeds ERPG-3 at 12 meters

ERPG = Emergency Response Planning Guideline, MEI = maximally exposed individual, TA = technical area, ppm = parts per million.

[a] ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective action (DOE 2004a).

[b] ERPG-3 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects (DOE 2004a).

Note: To convert meters to feet, multiply by 3.28.

Table D–20 Chemical Accident Impacts Under Seismic 2 Conditions

Chemical	Frequency (per year)	Quantity Released	ERPG-2 [a]		ERPG-3 [b]		Concentration	
			Value	Distance to Value (meters)	Value	Distance to Value (meters)	Noninvolved Worker at 100 Meters	MEI at Site Boundary
Hydrogen cyanide at TA-3-66 (Sigma Complex)	0.0005	13.5 pounds (6 kilograms)	10 ppm	140	25 ppm	86	18.6 ppm	0.252 ppm at 924 meters
Phosgene at TA-9-21	0.0005	1 pound (0.45 kilogram)	0.2 ppm	280	1 ppm	120	1.38 ppm	0.0252 ppm at 823 meters
Formaldehyde at TA 43-1 (Bioscience Facilities)	0.0005	14.1 liters (3.7 gallons)	10 ppm	180	25 ppm	110	31.3 ppm	Exceeds ERPG-3 at 12 meters
Chlorine gas released outside of TA-55-41 Plutonium Facility	0.0005	150 pounds (68 kilograms)	3 ppm	1,080	20 ppm	380	165 ppm	3.38 ppm at 1,016 meters
Nitric acid spill at TA-55-4 (Plutonium Facility)	0.0005	6,100 gallons (23,090 liters)	6 ppm	49	78 ppm	6.6	1.61 ppm	0.0189 ppm at 1,016 meters
Hydrochloric acid spill at TA-55-249	0.0005	5,200 gallons (19,684 liters)	20 ppm	185	150 ppm	64.5	65.9 ppm	0.652 ppm at 1,117 meters
Beryllium at TA-3-141 (Beryllium Technology Facility)	0.0005	110 pounds (49 kilograms) (powder) [c]	0.025 milligrams per cubic meters	282	0.1 milligrams per cubic meters	116	0.126 ppm	0.00427 milligrams per cubic meter at 880 meters

ERPG = Emergency Response Planning Guideline, MEI = maximally exposed individual, TA = technical area, ppm = parts per million.

[a] ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action (DOE 2004a).

[b] ERPG-3 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects (DOE 2004a).

[c] This quantity represents the total material at risk. A fraction (0.0006) of this solid would be released for the hypothesized scenario.

Note: To convert meters to feet, multiply by 3.28.

The Seismic 1 chemical releases would be repeated here. In addition, because of the increased severity of this event, beryllium, chlorine, nitric acid, and hydrochloric acid could be released in sufficient quantities to create plausible health effects near the release site. Exposure to beryllium can result in acute lung damage; elevated levels of chlorine and acids can cause respiratory dysfunction. The beryllium powder release could result from Beryllium Technology Facility structural failure in a Seismic 2 earthquake, with subsequent container breaching. Chlorine could be released as a result of line or tank failures. The integrity of the nitric and hydrochloric acid tanks could be compromised. It is assumed that their entire contents spill and are contained within the seismically qualified berms surrounding each tank. Release from these acid pools would then be by evaporation.

Table D–20 shows the concentration of each chemical, if it were released, at specified distances. The estimated frequency of this seismic event is shown in the table. The hydrogen cyanide, phosgene, and formaldehyde releases from the Seismic 1 event would also be released with this more severe Seismic 2 event; distances and environmental concentration levels would be unchanged from the former event. None of the additional releases would result in MEI exposure in excess of ERPG-3 levels. A noninvolved worker, if directly downwind from the release and unable to take evasive action, could be exposed to beryllium or chlorine in excess of ERPG-3 levels. The additional releases (except beryllium) are from TA-55, and its distance from the site boundary, together with the quantities potentially released, would prevent ERPG-3 exposure to the public. The inventory of beryllium kept at TA-3-141 is limited to minimize accident impacts.

D.4.3 Reduced Operations Alternative Impacts

The site-wide seismic radiological accident impacts from the Reduced Operations Alternative would be similar to those from the No Action Alternative, as given in Tables D–13 through D–18. SHEBA operations at LANL would cease under this alternative. Inspection of the tables shows that SHEBA operations are a small component of the site-wide seismic accident impacts at LANL; its elimination would not significantly alter the overall site risk profile from such an event. All other impacts in the tables are equally applicable for this alternative.

The chemicals of concern that could be released in a site-wide Seismic event are the same for the Reduced Operations Alternative as for the No Action Alternative. None of the chemicals identified for the latter are eliminated in this alternative. The information in Tables D–19 and D–20, then, is applicable to the Reduced Operations Alternative.

D.4.4 Expanded Operations Alternative Impacts

D.4.4.1 Site-wide Seismic 1 – Radiological Impacts

The Seismic 1 accident impacts from the Expanded Operations Alternative would be similar to those from the No Action Alternative. SHEBA operations at LANL would cease under the Expanded Operations Alternative. Its impacts are relatively small; deleting SHEBA impacts would not change the overall Seismic 1 risk profile of this alternative. Replacement risks from accident impacts would result from expanded waste management activities. Transuranic waste managed at DVRS would be moved offsite or to a new facility, the Transuranic Waste Consolidation Facility (TWCF), located in TA-50 or TA-63. The impacts from this new facility would be less than those of the existing facility because of the new location. The entries in Tables D–13 through D–15 reflect present DVRS operations because it would be active for most of the time period of interest. The accident impacts from DVRS bound the impacts of its replacement facility. Accident impacts for the new facility are described in Appendix H.

D.4.4.2 Site-wide Seismic 2– Radiological Impacts

The Seismic 2 accident impacts from the Expanded Operations Alternative would be similar to those from the No Action Alternative. SHEBA operations at LANL would cease under the Expanded Operations Alternative. Its impacts are relatively small; deleting its impacts would not change the overall Seismic 2 risk profile of this alternative. Replacement risks from accident impacts would result from expanded waste management activities. Transuranic waste managed at DVRS and the waste storage domes would be moved offsite or to a new facility, TWCF, located in TA-50 or TA-63. The impacts from this new facility would be less than those of the existing facility because of the new location and because less material would be stored, the rest being moved offsite. The entries in Tables D–16 through D–18 reflect present DVRS and the waste storage domes operations because they would be active for most of the time period of interest and because their accident impacts bound the impacts of the new facility. The TWCF accident impacts are described in Appendix H.

D.4.4.3 Site-wide Seismic 1 – Chemical Impacts

The chemicals of concern that could be released in a site-wide Seismic 1 event are the same for the Expanded Operations Alternative as for the No Action Alternative. No additional chemicals were identified in this alternative that would have impacts exceeding those for the No Action Alternative. The information in Table D–19, then, is applicable to the Expanded Operations Alternative.

D.4.4.4 Site-wide Seismic 2 – Chemical Impacts

The chemicals of concern that could be released in a site-wide Seismic 2 event are the same for the Expanded Operations Alternative as for the No Action Alternative. No additional chemicals were identified in this alternative that would have impacts exceeding those for the No Action Alternative. The information in Table D–20, then, is applicable to the Expanded Operations Alternative.

D.5 Wildfire Accidents

This section discusses the potential for a wildfire at LANL (LANL 2004) that could cause the release of hazardous radioactive and chemical materials, affecting the health and safety of LANL workers and the public. The discussion and analysis in Chapter 5, Sections 5.1 through 5.4 is largely extracted from LANL (LANL 2004).

D.5.1 Background

Wildfires were evaluated in the *1999 SWEIS* and were studied further following the Cerro Grande Fire in May 2000. The following sections provide background information on the potential for LANL wildfires since the *1999 SWEIS* was prepared.

D.5.1.1 Consuming Combustible Structures and Vegetation

A theoretical wildfire resulting in the exposure of humans to airborne radiation was one of several operational site-wide accident scenarios analyzed and reported in the *1999 SWEIS*. The health impact of the wildfire accident was 0.34 LCFs, resulting from an estimated population dose of 675 person-rem. The dose to the MEI member of the public was less than 25 rem, and the estimated frequency of occurrence was approximately once every 10 years. While the estimated radiological dose consequence of a wildfire accident was small, the high frequency of occurrence resulted in a risk (the product of the frequency and consequence) that was surpassed by only one other postulated accident in the *1999 SWEIS*.

The wildfire accident analysis assumed multiple source releases, including radiological inventories from buildings, suspended soils with environmental (very low) levels of contamination, and ash from burned vegetation (this ash also had very low levels of contamination). Since the analysis in 1999, radiological inventories in buildings have changed, the vulnerability of buildings to ignition by wildfire has changed as a result of tree thinning, more accurate and more comprehensive data have been compiled on concentrations of radionuclides in vegetation, vegetation fuel loads have changed, and the frequency of occurrence has possibly changed.

The LANL site and surrounding vicinity are generally forested areas with high fuel loading (Balice, Oswald, and Martin 1999; Balice et al. 2000). Wildfires are frequent occurrences on nearby U.S. Forest Service land, with obvious potential for encroaching on the LANL site, as demonstrated by recent events (Balice, Oswald, and Martin 1999, Balice et al. 2000). Recently, an analysis was completed to help determine areas of concern at LANL for continued wildfire risk that includes consideration of the extensive environmental changes since 1999. Based on the results of this analysis, areas of concern were determined; these areas are consistent with those found in another recent wildfire risk analysis (Balice et al. 2005). A particular scenario, a wildfire initiated to the southwest of LANL near the border of the Bandelier National Monument and the Dome Wilderness Area was postulated. While there is a potential for initiation of a wildfire at many locations within and near the LANL site, this location was considered to have the potential for the most widespread environmental impact to LANL because there is continuous fuel from these offsite locations to the southwest corner of LANL.

D.5.1.2 Recent Widespread Environmental Changes

Since completion of the *1999 SWEIS* wildfire analysis, the Cerro Grande Fire occurred adjacent to and on the LANL site. On May 4, 2000, the National Park Service initiated a prescribed burn on the flanks of Cerro Grande Peak within the boundary of Bandelier National Monument. The intended burn was a meadow of about 300 acres (120 hectares), located 3.5 miles (5.6 kilometers) west of TA-16, near the southwest corner of LANL. The prescribed burn was begun in the evening, but, by 1 p.m. the following day, the burn was declared a wildfire.

LANL's meteorological data showed above–average temperatures and low humidity for the first 10 days of the wildfire, with wind speeds averaging 6 to 17 miles per hour (10 to 27 kilometers per hour) and gusting from 27 to 54 miles per hour (44 to 87 kilometers per hour). Generally, winds tended to be from the southwest to west during this period. By day 5 of the wildfire, May 8, spot fires began to occur on LANL lands. By May 10, the fire moved into the Los Alamos townsite and was proceeding north and east across the TA-16 mesa top. The fire was moving eastward down Water Canyon, Cañon de Valle, Pajarito Canyon, and Cañada del Buey by May 11. Eventually the fire extended northward on LANL lands to Sandia Canyon and eastward down Mortandad Canyon into San Ildefonso Pueblo lands. The residential areas of Los Alamos and White Rock were in the fire's path, and more than 18,000 residents were evacuated. By the end of the day on May 10, the fire had burned 18,000 acres (7,280 hectares), destroyed 235 homes, and damaged many other structures. The fire also spread toward LANL, and although fires moved onto LANL land, all major structures were secured and no releases of radiation occurred. The wildfire was declared fully contained on June 6, having burned nearly 43,000 acres (17,400 hectares) of land extending to Santa Clara Canyon on Santa Clara Pueblo lands to the north of the townsite. LANL had approximately 6,757 acres (2,734 hectares) of low-burn severity; 844 acres (342 hectares) of moderate-burn severity; and 50 acres (20 hectares) of high-burn severity (Balice, Bennett, and Wright 2004).[3]

The Cerro Grande Fire of 2000 had an enormous adverse impact on forests on and around LANL. Immediately there were concerns about increased erosion and flooding and the potential impacts on contaminated soil and sediment. Seventy-seven contaminant potential release sites and two

[3] *The sum of these areas is approximately equal to 7,700 acres as cited elsewhere in this SWEIS.*

nuclear facilities at LANL that contain hazardous and radioactively contaminated soils and materials are located within floodplain areas. Without DOE action, these potential release sites and nuclear facilities could potentially release contaminants and materials downstream during rainfall events. Numerous cultural resource sites and traditional cultural properties are located in canyons or along drainage areas, and were at an increased risk of flood damage.

LANL conducted assessments and implemented on-the-ground rehabilitation efforts. Under the DOE Special Environmental Assessment (DOE 2000), LANL was to conduct mitigation measures and monitor the condition of the burned area annually. In all, LANL treated over 1,800 acres (728 hectares) with techniques similar to those used by the Burned Area Emergency Rehabilitation team. The project was successful, increasing vegetative cover on the severely burned units from around 0 percent to almost 45 percent. Most of the straw wattles that were installed held sediment onsite and allowed vegetation to grow. The LANL contractor developed best management practices for all potential release sites that were potentially impacted by the fire to eliminate contaminant transport.

The drought that began in 2000 in the southwestern United States, although not unprecedented, has been one of the most severe in 50 years (Breshears et al. 2005). Precipitation for this region was 25 percent below average during 2000 and 2001, and 65 percent below average through the summer months. The combined effects of prolonged drought and severe outbreak of bark beetles (*Ips confusus*) resulted in tens of millions of dead trees over thousands of square miles in Arizona, New Mexico, Colorado, and Utah (McHugh, Kolb, and Wilson 2003). Highest mortality levels are seen in ponderosa pine (*Pinus ponderosa*), douglas-fir (*Pseudotsuga menziesii*) and piñon (*Pinus edulis*) pine trees. Many areas in piñon-juniper habitat have had the entire stand of piñon die, leaving only juniper (*Juniperus monosperma*). Bark beetles in western North America have been documented to cause large areas of high mortality that have been linked to both drought and fire in the region (USDA 2002). The Pajarito Plateau, where LANL is located, had an average 85 percent tree mortality for trees over 5 feet (1.5 meters) tall from 2002 to 2003. This mortality left a mosaic of live and dead trees.

In order to decrease the risk from catastrophic environmental fire, LANL has undertaken a tree-thinning project that was begun in January 2002. The goal of this project was to reduce the threat of wildfire to forested areas and structures on LANL property and to enhance and maintain wildlife habitat and tree species diversity by ensuring vertical and horizontal heterogeneity of age class and structure throughout the forest, and to promote forest health. Tree thinning has been completed on 7,283 acres (2,947 hectares) and includes both ponderosa pine and piñon–juniper habitats (LANL 2005). Tree thinning and environmental changes were incorporated into the wildfire risk analysis of this SWEIS.

D.5.1.3 Wildfire Occurrence

D.5.1.3.1 General Approach

The following analysis of the risk of wildfire initiation and spread was taken from LANL 2004.

This analysis was largely based on data and results produced during earlier studies and field monitoring activities. A dataset of lightning strike locations and intensities was used to represent wildfire ignitions. Polygons (multi-sided geometric shapes) of previously modeled fires were used to evaluate the relative potential for fires to burn within the study area. Fuels data and an existing land cover map were used to characterize the fuels and fire hazards in the study region. It was assumed that lightning, modeled fires, and fuels characterizations represent ignitions, fire spread, and flammability, respectively. These are all important components of wildfire risk. The three intermediate results were weighted and combined in the geographical information system (GIS) software to create a preliminary relative risk rating for each cell in the study region. All analyses were completed using ArcView 3.2a GIS software. Cell (a term used in ArcView for a specific bounded surface area) resolution was set at 49 feet by 49 feet (15 meters by 15 meters).

D.5.1.3.2 Region of Interest

The study region was based on an area used for previous analyses of wildfire behavior (Balice et al. 2000). This included most of LANL and all of its areas west of TA-18. To the west, north, and south, the region of interest extends to the crest of the Sierra de los Valles and the eastern portion of the Valles Caldera National Preserve, the northern extent of the Los Alamos townsite, and Frijoles Canyon, respectively. The typical vegetation in this area consists of piñon-juniper woodlands, ponderosa pine forests, mixed conifer forests, aspen forests and grasslands. Occasional barren areas, shrub lands and spruce-fir forests can also be found in the study region. Numerous developed areas, including the Los Alamos townsite and TAs at LANL, are also interspersed throughout the study region.

D.5.1.3.3 Lightning Strike Densities and Intensities

Lightning strikes that were less than 100,000 amps in intensity were removed from the dataset. Lightning strikes that were located outside of a test region were also removed from the dataset. The 131 remaining lightning strike locations and their relative intensities were analyzed in ArcView. From these point locations, a map of densities by relative strike intensities was created and scaled from 0 to 1, with 1 representing the greatest combined strike density and intensity. The cell-based output of scaled values represents the relative tendencies that fires would be ignited within the polygons.

D.5.1.3.4 Modeled Fire Polygons

To assess the potential for fires to burn within each ArcView cell, wildfires were simulated from each lightning strike location using scenarios that reflected conditions in the Los Alamos region for the 1999 time period (57 lightning strikes) and the 2002 time period (49 lightning strikes), respectively. FARSITE was used as the modeling software (USDA 1998). FARSITE had previously been parameterized with locally collected data representing the fuels and fire hazards of the Los Alamos region. The parameterized fire behavior modeling system had also been validated against the burn histories of known fires.

The databases representing the 1999 time period were derived from vegetation and fuels conditions that were present in the Los Alamos region before the Cerro Grande Fire, before the initiation of major thinning and fire hazard reduction activities, and before the initiation of drought induced mortality. All other conditions for fire behavior simulations were assumed to be those which existed immediately before or during the Cerro Grande Fire. The databases representing the 2002 time period incorporated changes that resulted from the Cerro Grande Fire, large-scale forest thinning activities, and tree mortality.

Each simulation produced a polygon representing the potential area burned by a wildfire. These multiple theme layers or polygons were then superimposed in the GIS and the total number of fire polygons that occurred in each cell was summed. For both the 1999 time period and the 2002 time period, the greatest number of simulated fires in any given cell was 11. Cell values were then scaled from 0 to 1 based on these values, with 1 representing those cells where 11 simulated fires occurred. The final scaled values represent the relative tendency of a fire to burn through a cell under the conditions of the simulation. Those cells with more fires were assumed to be at greater risk of a fire actually burning through that cell.

D.5.1.3.5 Fuel Conditions

The fuel model concept, canopy heights, and percent canopy cover were used to model the fuel conditions at each ArcView cell. Values for these parameters were established from previous field sampling that had been conducted throughout the Los Alamos region from 1997 through 2004. The fuel models were ranked by their relative ability to support more intense fires. Similarly, 100 feet (30 meters) was assumed to be the maximum canopy height, and all other canopy heights were ranked proportionally to this maximum value and scaled from 0 to 1. For canopy cover, 100 percent cover was set as the maximum possible and the actual percent canopy cover values were rated proportionately between 0 and 1.

Previously developed land cover classification systems for assignment of fuel model, canopy heights, and percent canopy cover values to each land cover class were used. This was performed for conditions that were typical of the 1999 and 2002 time period. These scaled class assignments were applied to ArcView versions of land cover maps that had been developed before and after the Cerro Grande Fire.

D.5.1.3.6 Wildfire Model Development

The five data layers of lightning, modeled fires, and fuel conditions (3 layers) for each time period were mathematically combined in the GIS to assess spatial trends of fire risk across the study region. Equal weight was given to each of these three major risk groups, according to the following relationship:

> {Density of lightning strikes by their relative intensity + relative number of simulated fires + [relative canopy height + relative percent canopy cover + relative fuel model]/3}/3.

Finally, the values for these calculated fire risks were scaled from 0 to 1. The analysis was repeated for conditions that existed in approximately 1999. This was before the Cerro Grande Fire, before extensive thinning was initiated, before rehabilitation treatments were applied to the forests of the region, and before the onset of major mortality events. Then the process was repeated for the 2002 conditions, after the Cerro Grande Fire, after the thinning of approximately 7,000 additional acres (2,800 hectares), and after the onset of tree mortality.

D.5.1.3.7 Wildfire Model Results

Results indicate that the risk of wildfires within the study region is not homogeneous through space and time. With regard to time, the relative wildfire risks are seen to decrease from the 1999 time period (see **Figure D–1**) to the 2002 time period (see **Figure D–2**). The greatest decrease in the wildfire risk appears to have taken place in the mountainous regions on the western boundary of LANL and further to the west, and in the mesa and canyon regions of the western and central portions of LANL.

Spatial variations in wildfire risk for the 2002 time period show a general decrease in risk from the mountainous regions in the west to the lower elevations in the eastern portion of the study region. A general ranking of the specific areas for their relative risk is also possible.

First, the greatest fire risk occurs along the Pajarito Ridge from Highway 501 to the Pajarito Ski Area.

Second, the next greatest fire risk occurs in the southwest corner of LANL, adjacent to the Back Gate.

Third, the intervening areas along Highway 501 and the western boundary of LANL are also relatively high in fire risks.

Fourth, portions of the mesa-canyon areas between TA-40 and TA-21 are relatively high in fire risks. This is particularly true for the north-facing slopes of the canyons, although some of the other topographic positions in this area resulted in lower levels of fire risks.

Fifth, the remaining portions of LANL and its immediate surroundings are relatively less at risk from wildfires.

D.5.2 Current Wildfire Hazard Conditions

This section discusses the current wildfire hazard conditions and likelihood, reflecting changes that have occurred since the late 1990s. The analysis is taken from LANL 2004a.

D.5.2.1 Changes to the Fuels and Fire Hazard Conditions in the Past 5 Years

Current fuels and fire hazard conditions in the Los Alamos region are not the same as those that existed in the late 1990s. This is reflected in the most credible wildfire scenario that would be expected in the present time period, which is considerably different from what would have been expected before 2000. In the wildfire scenario that was reported in the *1999 SWEIS* (DOE 1999a), fuels were heavy and continuous throughout most of the mixed conifer forests of the Sierra de los Valles, and extended eastward to the ponderosa pine forests on most of the western portions of LANL property. As ponderosa pine forests transitioned to piñon-juniper woodlands toward the eastern half of LANL, the canopy heights and the total fuel loads were reduced somewhat, but maintained the continuous nature of their over story cover. These heavy and continuous fuels, especially in the mountainous environments, coupled with the southwest-to-northeast wind patterns that are typically prevalent during the fire season, suggested a general wildfire scenario that was validated by the Dome Fire and by the Cerro Grande Fire.

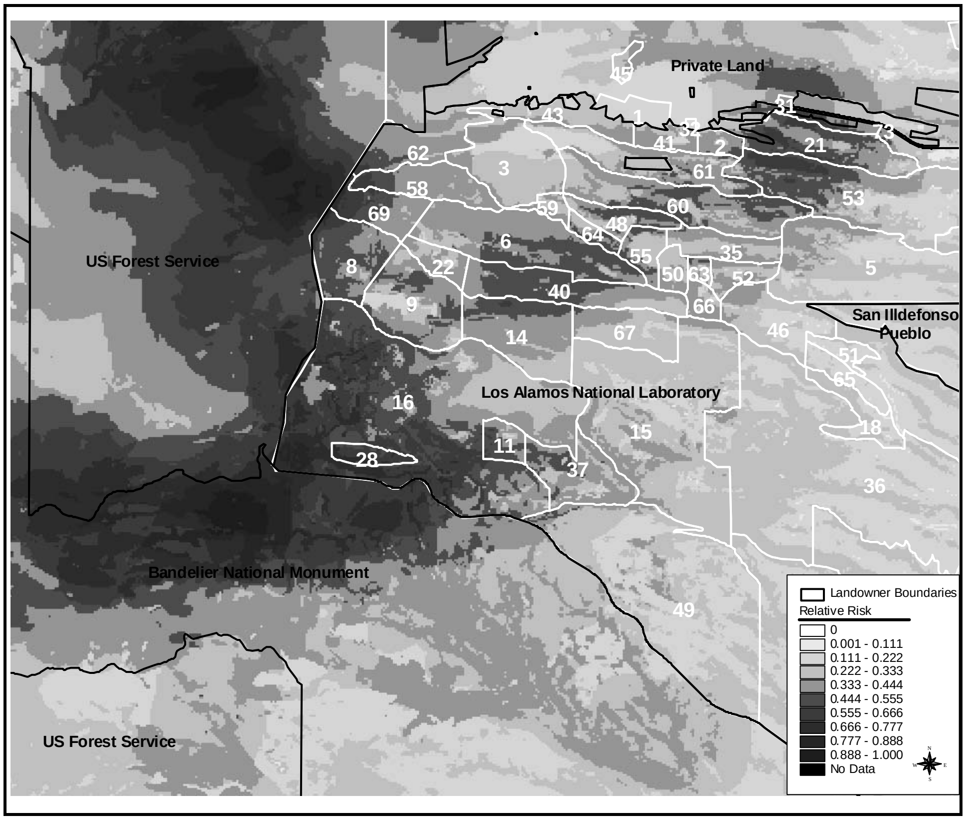

Figure D–1 Relative Risk of Wildfire in the Los Alamos Region (1999)

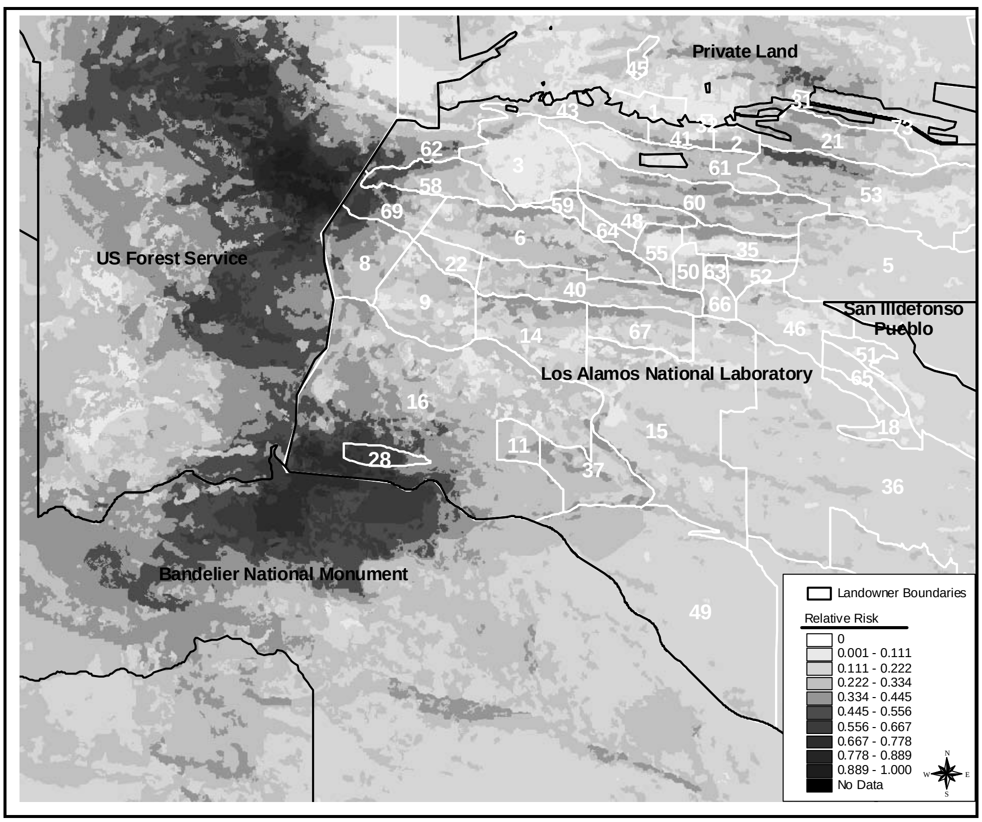

Figure D–2 Relative Risk of Wildfire in the Los Alamos Region (2002)

In the general wildfire scenario of the 1990s, fire would be ignited by lightning or by humans in the mountains during high to extreme fire danger levels. A small fire of this type would burn lightly for a day or two until the combination of temperature, humidity, and wind worsen to the point that the fire extends from the ground surface through the fuel ladders into the forest over story. At this time, the winds would carry the fire through the tree crowns from the mountains in a northeasterly direction toward LANL. The fire would continue to spread across LANL for up to 10 days. During this time, all unprotected buildings and facilities in its path would be destroyed. Suppression of the fire would be impossible until the weather conditions moderated sufficiently to allow for the application of effective suppression measures.

Since the writing of the *1999 SWEIS*, several aspects of the wildfire conditions in the Los Alamos region have changed significantly. However, some aspects of the wildfire conditions in the region have not changed. For example, ignition sources have not changed since the *1999 SWEIS*. During both time periods, fires would most likely be ignited by lightning or by humans. Moreover, ignitions would typically occur most prevalently in the mountainous environments to the west of LANL. Topographic conditions in the Los Alamos region have also not changed since the *1999 SWEIS*. The mountainous environments to the west of LANL, and the canyon-mesa environments at LANL present difficulties in management and suppression of fires, and create safety and management issues related to transportation and movements across these topographic barriers. The patchwork of land management agencies in the Los Alamos region has also not changed since the *1999 SWEIS*. This creates unique problems to wildfire hazard management that can only be resolved through strong interactions and collaborations among the individual agencies.

Some aspects of weather have changed since the *1999 SWEIS*, and some have not. The severe wildfire weather conditions tend to occur from mid-April to early July, and these have not been altered since 1999. Similarly, there is still a significantly strong tendency for intense winds to occur during this time period, and the direction of these winds tends to be from the southwest to the northeast. Moreover, the density of lightning strikes is high during the latter portions of the wildfire season, and this has not been altered since the writing of the *1999 SWEIS*. What has changed with respect to weather conditions since the time of the *1999 SWEIS* is that the climate has grown significantly hotter and drier. This is similar to the 1950s drought in that the precipitation levels have been somewhat similar. However, this is in contrast to that drought in that recent temperatures have been significantly higher (Breshears et al. 2005).

The levels of fuels in the Los Alamos region are the aspects of wildfire hazards that have been extensively changed since the *1999 SWEIS*. First, the Cerro Grande Fire greatly reduced the fuels in more than 42,000 acres (17,000 hectares) of forested landscape at LANL and to the west of LANL. This is especially true in the severely burned areas where reestablishment of fuels has been limited to regrowth from sprouting shrubs and from seeded grasses. In contrast, regrowth of vegetation in the lightly burned and moderately burned sections of the Cerro Grande Fire have resulted in very little net change in the levels of fuels in these areas. Moreover, reseeding with grasses in the severely burned areas of the Cerro Grande Fire, along with other rehabilitation techniques, has resulted in major changes to the post-fire fuel conditions. Immediately after the fire, severely burned forests were essentially unburnable. However, with the establishment of seeded grasses and with the addition of dead trees that have fallen to the ground, many of these areas can now support a surface fire.

In addition to past fires, fire hazard reduction activities in forests and adjacent to facilities at LANL have altered the fuel structures. Before 1997, the forests and woodlands at LANL were essentially unmanaged and severely overstocked with trees and shrubs. The result was a situation that was dangerously high in fuels and fire hazards throughout most of the forests and woodlands at LANL. Between 1997 and 1999, approximately 800 acres (324 hectares) of ponderosa pine forest on the western perimeter of LANL and near critical facilities were thinned from below. These fire hazard reduction activities increased dramatically after the Cerro Grande Fire. Between 2001 and 2003, approximately 6,000 acres (2,428 hectares) of ponderosa pine forests and piñon-juniper woodlands were thinned. These fire hazard reduction activities focused on creating defensible space around critical buildings and facilities, underneath power lines and along transportation corridors, and in the surrounding forests and woodlands.

D.5.2.2 Potential Wildfire Scenarios

The results of the risk of wildfire analysis that incorporates altered fuel conditions that have occurred in the past few years suggest the heightened likelihood of some general wildfire scenarios to occur, relative to other scenarios at LANL. Wildfires that occur today would still be ignited by lightning or by humans. These fires would tend to be ignited in the mountainous regions to the west of LANL, but fires could also be started on LANL. High winds during the fire season, from mid-April to early July, would still tend to carry actively burning wildfires from the southwest to the northeast. This general scenario is consistent with another recent wildfire risk analysis for LANL (Balice et al. 2005). Early suppression of wildfires is important to the successful protection of buildings and facilities. Once these fires enter the canopy of forests, they are difficult to control until weathers conditions moderate.

The major impact of fire hazard reduction activities in recent years at LANL is that fires would tend to remain on the ground surface, and would also tend more readily to drop from the canopies back to the ground surface. This, in combination with the creation of defensible space adjacent to LANL facilities, would facilitate management and suppression with the result that buildings and facilities would be easier to protect.

With the greatest modeled risk from wildfires occurring along the Pajarito Ridge and along the margins of the Frijoles Canyon, the risk to LANL would still largely arise from the west and the southwest. Thus, TA-16, TA-28, TA-58, TA-62, and TA-69 would be at the greatest risk from wildfires. With the second greatest risk from wildfires occurring along the western borders of LANL, TA-8 and TA-9, and portions of TA-16 would be at risk from wildfires arising in this area. Secondarily, TA-3, TA-6, TA-11, TA-14, TA-22, TA-37, TA-40, and TA-59 would also be at risk from fires arising along the western boundary at LANL. In all of these cases, fires would enter the canyon environments on LANL property. This would create difficulties for control and management, with an increase in danger to adjacent buildings and facilities.

Fires that originate from within the boundaries of LANL would likely be ignited at firing sites at central locations of the site. These would primarily impact TA-14, TA-15, TA-40, and TA-67. Numerous canyons dissect this area, and this would add to the difficulties of suppressing these fires as they spread across adjacent mesas from canyon to canyon. In addition, the canyon environments contain conditions, including topographic barriers, heavy fuel loads on north-facing aspects, and modified canyon wind patterns, that would complicate the direction of wildfire spread. The result is that fires would tend to spread readily in down-canyon and up-canyon directions, as well as traveling across mesas or via airborne embers to adjacent canyons.

D.5.2.3 Frequency of Wildfires

The probability component of the risk equation reported in the *1999 SWEIS* only considered the advancement of a large wildfire to the LANL boundary, and then assumed that the fire necessarily continued on a path through LANL, reaching and igniting LANL buildings and causing a radiological release.

The frequency of a large fire encroaching on LANL (1 in 10 years) was estimated in 1999 as the joint probability of ignition in the adjacent forests, high to extreme fire danger, failure to promptly extinguish the fire, and fire-favorable weather. The frequency estimate for ignition in the adjacent forests was based on a 21-year period (1976 to 1996) and probably has not changed appreciably in the years that have passed since. Fire ignitions have continued to occur in adjacent forests. Periods of high to extreme fire danger have continued to occur frequently during the summer months, and fire-favorable conditions have continued as well. The estimated likelihood of a fire reaching a LANL boundary did not include the likelihood of a fire advancing across LANL to encroach on buildings containing (appreciable amounts of) radiological materials, the likelihood of buildings igniting, and the likelihood of a release occurring once buildings are assumed to ignite. The likelihood of a fire encroaching on a building containing radioactive material is dependent on, among other factors, fuel load and continuity of fuel leading up to the space surrounding the buildings. The likelihood of a nuclear facility igniting is dependent on the joint probability of fuel load indices for fuel adjacent to buildings, slope on which the adjacent fuel loads exist, and the combustibility of buildings. This factor was quantified in 1999 and has been updated recently. The likelihood of a release would be related to the damage ratio (likelihood that the material at risk was actually impacted by the accident) and the leak path factor (likelihood that confinement, if any, is breached). While the probability of a large fire encroaching on LANL remains moderate to high, depending on location, probably still on the order of once per 10 years (0.1 per year), the probability of a LANL facility containing an appreciable radiological inventory being ignited by a wildfire and releasing some or all of the inventory has been reduced somewhat by the "defensible space" thinning and by the reductions in fuel by the Cerro Grande Fire.

Since the probability estimate for the *1999 SWEIS* stopped at the LANL boundary, there is no value for the probability of the fire advancing across LANL to nuclear facilities, igniting buildings, and causing a release. Without this value, an assessment of how this probability might have changed cannot be made. Gonzales, Ladino, and Valerio (2004) conservatively estimated that there is a 50 percent chance that the three factors just mentioned occur, and combined this probability value (0.5) with the assumed probability for a wildfire reaching the LANL boundary (0.1). This resulted in a conservative estimate of the probability for a release to occur resulting from a wildfire and resulting in radiological exposures of 0.05 per year. This translates to a 5-in-100-year chance of occurrence, which is equal to once in 20 years. This estimate is in agreement with the draft Documented Safety Analysis for Area G. The fact that the Cerro Grande Fire did not result in the ignition of a LANL nuclear facility is evidence that thinning works and preventative maintenance will keep key facilities safer from wildfire than in the past.

D.5.2.4 Conditions that Favor Wildfire

In view of the present density and structure of fuel surrounding and within LANL, as well as the occurrence of five major fires in the past 50 years it is evident that there is the potential for wildfire occurrence at LANL. Some protection is afforded LANL by the fire scars of the previous Dome and La Mesa Fires, but there is ample fuel continuity remaining to bring an offsite wildfire to the southwest and western boundary of LANL. The current analysis takes into effect the environmental changes and fuel reduction mitigation that have taken place due to the Cerro Grande Fire.

The probability of high to extreme fire danger is determined by the frequency of meteorological conditions of low precipitation for 2 to 3 weeks preceding; low relative humidity for 3 consecutive days; and high temperatures. When the high to extreme fire danger exists in New Mexico in May through July, there are certain to be multiple ignition sources (from lightning and human causes). There is a high frequency of lightning and lightning-caused fires in the Jemez Mountains that were used in the analysis of fire risk. The frequency of a large fire encroaching on LANL is estimated as the joint probability of ignition in the adjacent forests, high to extreme fire danger, failure to promptly extinguish the fire, and a 3-day spell of southwesterly to westerly wind over 11 miles per hour (5 meters per second), low humidity, and no precipitation.

D.5.2.5 Determining the Joint Probability of Occurrence of Weather and Fire Danger Conditions

The probability of occurrence of the weather and fire conditions needed for a wildfire were determined using wind data and fire danger data for April through June of 1980 through 1998. During these months, fire risk and frequency are greatest. Note that site-wide fires also are possible, but less probable, in other months besides April through June; thus, the annual frequency of fire–favorable weather is somewhat greater than quantified for April through June.

In general, wind direction at any location varies and does not persist in a single direction for a few days. LANL is no exception. At LANL, persistent daytime winds are interrupted for a few hours when nighttime drainage winds occur. However, granting short interludes of drainage flow, there are many instances in which a dominant direction, such as southwesterly, westerly, northerly, can exist for 3 days without precipitation.

For determining fire-favorable weather frequency, 15-minute average wind data from the lower level of the TA-6 and TA-59 meteorological towers was used. For each day in April through June of 1980 through 1998, an average afternoon wind was calculated from the 15-minute data in order to eliminate local diurnal changes in wind speed and direction that are common to the area. Average afternoon wind speeds of greater than 10 miles per hour (4.5 meters per second) are chosen to represent strong winds. While this threshold may seem low for a strong wind, wind gusts of over 30 miles per hour (13 meters per second) and sometimes over 40 miles per hour (18 meters per second) are seen on most days when the afternoon average wind is above 10 miles (16 kilometers) per hour. The wind direction thresholds are set at 180 degrees (southerly, meaning from the south) through 292.5 degrees (west-northwesterly). Three-day periods from the same dataset were then examined to determine if the precipitation, wind speed, and wind direction fell above (or within) set thresholds. All 3-day periods falling within the set limits were then extracted.

The results show that it is not uncommon to see a 3-day period exhibiting the selected characteristics in a given year, and that when such a 3-day period appears, it is likely that more than one such period will occur within that year. Specifically, the resulting statistics show that of the 19 years examined, 5 of them displayed at least one 3-day period within the limits, or one every 4 years. Of these 5 years, 4 had an average of 3.6, 3-day periods. (An instance of 5 days in a row is counted as three, 3-day periods.) This comes to 15.4 instances in 19 springs.

In summary, fire-favorable weather conditions occur on the order of once per year; the ignition sources are prevalent; and fire fighting is hampered by limited accessibility. Therefore, analysis concludes that a major fire moving up to the edge of LANL is not only credible but likely, probably on the order of 0.10 per year. This frequency is the same for all alternatives.

D.5.3 General Wildfire Scenario

D.5.3.1 Description

The SWEIS wildlife scenario used in 1999 predicted a path and outcome very similar to the Cerro Grande Fire. Due to the extent and size of the Cerro Grande Fire and subsequent fire mitigation actions completed since the *1999 SWEIS*, a new fire risk analysis was completed in order to incorporate the environmental changes and lessons learned from the Cerro Grande Fire.

The scenario fire begins midday in the late April through June timeframe, at a time of high or extreme fire danger, and is not extinguished in the first hour. The initial location is in an area populated with heavy ponderosa pine fuels that are found between roughly 6,500 and 8,200 feet (1,980 and 2,500 meters) elevation. As the fire grows, local jurisdictions respond to the fire, but are not effective due to characteristics such as remoteness, travel time, lack of road access, and fire behavior. Resources from more distant jurisdictions are alerted, but cannot arrive in a short time because of distance, limited roads, and opposing evacuation traffic. It proves impossible to put out the fire with the available resources and existing forest access before it enters LANL. Unlike the Water Canyon Fire (greater than 3,000 acres [1,214 hectares] in June 1954), La Mesa Fire (15,300 acres [6,191 hectares] in June 1977), Dome Fire (16,500 acres [6,677 hectares] April 25 to May 5, 1996), Oso Fire (greater than 5,000 acres [2,023 hectares] in June 1998), but very much like the Cerro Grande Fire in May 2000 (43,000 acres [17,401 hectares]), the weather does not change in time to prevent the fire from sweeping across the western part of LANL and into the townsite.

This specific analysis assumes a common meteorological situation that favors the fire. In this scenario, the fire begins about 10 a.m., reaches a size of 1,000 acres (400 hectares) in 3 hours, and becomes a well-developed crown fire on a broad fire front containing 6,000 acres (2,400 hectares) on the second day. Like the La Mesa Fire, at times it advances at a rate of 0.5 miles (0.7 kilometers) per hour. It starts spot fires 0.5 to 1.25 miles (0.8 to 2.0 kilometers) in advance, aided by prevailing southwest winds of 20 miles per hour (9 meters per second) and low daytime humidity. It easily jumps canyons and existing fuel break lines around LANL and the townsite, similar to the Cerro Grande Fire.

The daytime convection column reaches to 20,000 to 25,000 feet (6,000 to 7,600 meters). In the Oso Fire, the fire burned as actively at night as in the day, with flame heights on the order of 100 feet (30 meters). In this scenario, in order to have a conservative (low height) plume rise, at night the temperature drops and the relative humidity increases. The nighttime plume rise is then about 2,000 feet (600 meters). The fire regains its intensity at 10:00 a.m. each day. Following fire passage, the smoldering remains of vegetation and structures emit smoke and contaminants at the surface level.

The fire reaches State Road 4 and State Road 501, the southwest edge of LANL, at noon on the second day. Protective actions are already underway by LANL, such as relocating some radionuclides and barricading some windows, and releasing nonessential personnel following existing emergency plans. The fuel break along these roads proves inadequate. At this point, the fire has progressed in areas where access is limited, hampering fire suppression activities due to concern for the safety of the firefighters. A control line is established at Pajarito Road and resources are concentrated there. Consequently, Pajarito Road is closed and not available for public evacuation. The fire burns forest to the west of and within LANL, but its eastern extent within LANL is constrained by piñon-juniper woodlands and defined by fuel continuity and density.

From the completed specific analysis for fuel loads and prediction of fire risks, it is estimated the TAs most at risk include TA-8, TA-16, TA-28, TA-58, TA-62, and TA-69. This differs slightly from TA-15, TA-37, and TA-66 that were used in the previous wildfire scenario. Following the continuous fuel lines and steered somewhat by southwesterly winds, the fire enters and crosses Pajarito Canyon and Twomile Canyon, and by 1 a.m. of the third day burns up to the Pajarito Road control line just west of TA-66.

Although it would be expected that the control line would contain most fires, in this conservative accident scenario, an adverse meteorological situation exists where the wind picks up to 54 mph (24 meters per second**)** as it did in the Cerro Grande Fire, causing the fire to cross State Road 501. On the LANL site, the fire is assumed to consume all combustible structures in its path that are evaluated as having moderate or higher risk from wildfire under the LANL Building Appraisal Program. The fire also exposes the surface of contaminated earth previously protected by vegetation in the firing sites and canyons. This text separately discusses the exposures from fire burning the soil cover and suspending the underlying soil and the exposures from burning structures. Exposures from the latter are calculated individually, thus enabling the assessment of fires of lesser extent than the site-wide fire.

This accident analysis does not consider offsite damage directly caused by the flames and smoke from LANL fires, and does not address the direct effects of the fire on the townsite. It is recognized that there is continuous fuel joining the National Forest and the residential areas, and that fires in the canyons at LANL also could propagate into the townsite.

D.5.3.2 Dispersion Meteorology, Thermal Energy, and Soil Resuspension Following the Fire

The wildfire radiological release exposure analysis was performed using the same computer code used on the other radiological release scenarios described in this appendix, MACCS2. That code was exercised stochastically, sampling each hour of an annual meteorological dataset and using that hour as the initial conditions for plume transport. The reported doses are the mean values of each of these trials. Because the wildfire can occur most frequently in the period of April through June, the meteorology for those months was extracted from a recent 4-year dataset (2000 through 2003) of hourly meteorology to form a synthetic annual dataset consisting of April through June 2000 through 2003 (with meteorology from July 1, 2003, filling out the final day of the set). The MACCS2 wildfire analysis used this synthetic meteorology dataset.

The wildfire chemical release exposure analysis was performed using ALOHA, the same code used in the other chemical release scenarios described in this appendix. That code uses deterministic meteorology, such as a single wind speed and stability class, to calculate downwind dispersion. Table D-2 shows that stability class D and 7.8 mph (3.5 meters per second) wind speed represent median dispersion conditions for the synthetic dataset used in the MACCS2 analysis.

Exposures were calculated at 330 feet (100 meters) and the nearest public access to a release. These exposure locations are consistent with those chosen for the other scenarios included in this appendix. In the event of a wildfire scenario such as that considered here, the location of the public and onsite personnel such as firefighters might not correspond to those associated with the other scenarios considered. Chemical exposure at an additional location, 3,300 feet (1,000 meters) from each release, is therefore included. Radiological exposures at additional downwind distances, including 3,300 feet (1,000 meters), from each release are given in Section D.7.

The thermal energy of the contaminant plumes is a strong determinant of plume exposure. The greater the energy, the greater the plume buoyancy, and the less impact on receptors along the ground. As described in the previous subsection, the daytime plume rise could reach up to 25,000 feet (7,600 meters), while the nighttime plume rise is conservatively assumed to be only 2,000 feet (600 meters). MACCS2 was run with the meteorological dataset described above and a plume heat input of 20 megawatts was found to result in a plume rise of approximately 2,000 feet (600 meters). That heat input was used for the fire phase of all radiological releases. ALOHA conservatively assumes no heat input and, therefore, no buoyant rise due to heat is included in the chemical exposure calculations.

Following the fire release, a 24-hour wind suspension release period is assumed. It is thought that after the fire has passed, mitigation may not occur for this time period. An airborne release rate, 4×10^{-6} (4 parts per million) per hour, is chosen that reflects that the contamination remaining at the source will likely be covered with fire debris.

D.5.3.3 Exposures from Burning Vegetation and Suspended Soil

Suspended ash from vegetation and suspended soil contributed about 7 percent (approximately 50 person-rem) of the total population radiological dose reported in the *1999 SWEIS*. Concentrations of radionuclides in vegetation at LANL were largely unavailable when that SWEIS analysis was performed in the late 1990s. Given plant and soil uptake coefficients for some radionuclides in the published literature, concentrations of radionuclides in plants were largely based on concentrations in soil. Since the *1999 SWEIS*, data have been compiled on concentrations of radionuclides in vegetation at LANL. Comparing data used in the *1999 SWEIS* with more recent data on concentrations of radionuclides in plants, perspective can be gained on the change in vegetation as a radiation source term for wildfire. One concentration used in the *1999 SWEIS* was 320 micrograms (µg) uranium per gram (g) of dry vegetation, which was from a sample collected in 1975 where uranium concentrations in surface soils were 20 to 3,500 times background levels. This compares to maximum concentrations of 0.65 µg/g-dry in the bark of shrubs that were rooted in transuranic waste material, 0.073[4] µg/g-dry in under story vegetation collected at one of 12 LANL Environmental Surveillance Program onsite locations in 1998, 0.066[3] µg/g-dry in over story vegetation at one of the same 12 locations and same year, 0.05[3] µg/g-dry in pine needles from TA-16 in 1985, 0.72[5] µg/g-dry in over story vegetation at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility in 2002; and 1.5[6] µg/g-dry in piñon tree bark at a firing site in 2001 (Gonzales et al. 2003). Other than total uranium, the *1999 SWEIS* does not identify the concentrations used in source term calculations. Ignoring the other radionuclides, and based on the comparison of the total uranium concentration assumed in the earlier SWEIS with other, more recent data on concentrations of total uranium in plants, the source term from vegetation used in the *1999 SWEIS* is still bounding of any that would be calculated using more recent concentration data. The predicted MEI dose from vegetation and soil in a site-wide fire remains less than one millirem. Although the Cerro Grande Fire burned only about 7,500 acres (3,040 hectares) of forest within LANL, the estimated inhalation dose to a maximally exposed individual based on measurements of 0.2 millirem (LANL 2001) supports the hypothesis that vegetation (and soil) contributes very little radiation dose.

The effect of the existing radioisotope concentration in the soil in and around LANL on the calculated radiological consequences of a postulated wildfire was evaluated. Environmental surveillance data from the top 2 inches of soil measured in the 2001 through 2004 time period was used. These measurements were made for the following radioisotopes: tritium, strontium-90, cesium-137, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239, plutonium-240, and americium-241. Assuming a wildfire occurred that burned the same 43,000 acres (17,400 hectares) as the Cerro Grande Fire and that the mean radioisotope soil concentration was the same as the mean measured for the onsite LANL areas, the airborne respirable source term was calculated to be approximately 10 curies of tritium and 0.2 curies of uranium and transuranic radioisotopes. The total released respirable source term for all the buildings affected by the postulated wildfire accident in Appendix D is approximately 1.45×10^6 curies of tritium and 100 curies of uranium and transuranic radioisotopes. Therefore, the conservatively calculated soil-released source term from a Cerro Grande size fire is a factor of about 500 to 100,000 times smaller than the source term released by buildings affected by the fire. This much smaller magnitude of source term, coupled with the fact that it would be released over a very large distributed area, shows that the radiological effect of releasing radioisotopes in the soil during a large fire at LANL is insignificant as compared to the radiological consequence of the fire's effects on certain buildings at LANL.

[4] *Computed using ash/dry weight ratio of 0.1 from Fresquez and Ferenbaugh (1999).*
[5] *Computed using ash/dry weight ratio of 0.08 from Fresquez and Ferenbaugh (1999).*
[6] *Computed by converting radioisotopic data to uranium mass data and using ash/dry weight ratio of 0.029 for bark from Gonzales et al. (2003).*

D.5.4 Methodology

D.5.4.1 Evaluation of Building Fires

The *1999 SWEIS* analyzed potential individual and population radiological and chemical exposures from buildings burning as a result of wildfire initiation. Each building was first screened for its vulnerability to wildfire. Building vulnerabilities were updated in 2004 for this analysis. The building vulnerabilities at TA-54 and the Weapons Engineering Tritium Facility (WETF) in TA-16 were validated in the field in order to incorporate the many fuel load mitigations that occurred in the recent past. Those buildings that were evaluated as vulnerable were then screened for chemical and radiological inventories that were updated in May 2004.

Criteria and Process for Determining Building Vulnerability to Wildfire

The evaluation of vulnerability to wildfire is on the basis of building construction, materials and exposure, slope, and the quantity and structure of external fuel as described below. The total wild land fire vulnerability of over 500 buildings is frequently updated by the LANL Fire Protection Group. The vulnerability is the product of the structure hazard times the sum of the fuel hazard and slope hazard, as defined below.

Structure Hazard

The structure hazard rating considers the combustibility of the exterior structure:

- Underground – 0
- Noncombustible exterior (windowless) – 1
- Noncombustible exterior (window exposures) – 2
- Combustible exterior – 3

Fuel Hazard

The fuel hazard is the product of two components, fuel loading and distance factor. Fuel loading is taken as 0 for short grass and asphalt, and for other conditions is determined by the fuel model type, as described in *Aids to Determining Fuel Models For Estimating Fire Behavior* (Anderson 1982).

The distance factor (DF) expresses the distance of the fuel from the structure:

- DF–0 – distance is greater than 4 times the height of the fuel.
- DF–1 – distance is greater than 2 times the height of the fuel.
- DF–2 – distance is the height of the fuel.
- DF–3 – distance is less than one-half the height of the fuel.

Slope Hazard

Exposing slopes are rated as follows:

Slope Hazard	*Slope*
5	Mild (0 to 5 percent)
10	Moderate (6 to 20 percent)
15	Steep (21 to 40 percent)
20	Extreme (41 percent and greater)

The total vulnerability is then calculated as the product of the structure hazard times the sum of the fuel hazard and slope hazard. This number is converted to a word description as follows:

Numerical Rating	*Vulnerability*
0 to 5	None
6 to 49	Very Low
50 to 79	Low
80 to 149	Moderate
150 to 259	High
260 and above	Extreme

Note that this method does not estimate the probability that a wildfire will consume the building. Rather, it quantifies the relative vulnerability of a building to wildfire on the basis of the conditions immediately surrounding a building and the construction type for each building. **Table D–21** lists the buildings that have a Moderate or higher risk. Other buildings have no significant amounts of MAR and were not evaluated for this accident analysis.

Since 1999 when the results of this vulnerability assessment were first reported, a reduction in vulnerability from 51 to 21 buildings classified as Moderate or higher has been achieved, largely as the result of clearing or thinning the forested areas (defensible space) immediately adjacent to the buildings. More importantly, buildings of concern that are located in the wildfire high-risk area, such as WETF in TA-16, have been downgraded to Low vulnerability.

The *1999 SWEIS* analysis assumed that buildings with a Moderate, High, or Extreme wildfire vulnerability burned and released their entire content of radiological inventories. A reduction in the wildfire vulnerability of key buildings through reductions in the fuel load around the building could substantially reduce the likelihood of the building igniting and could also reduce the release of radiological materials by lowering the intensity of the fire. Since 1999, however, the wildfire vulnerability of two (Buildings 229 and 230) formerly high risk waste storage domes at TA-54 has been lowered to Moderate. The WETF wildfire vulnerability has been reduced from Moderate to Very Low.

Table D–21 Evaluation of Vulnerability of Los Alamos National Laboratory Buildings to Wildfire

Technical Area	Building	Wildfire Risk	Nuclear Facility	Hazards	Construction Type [a]
03	0016 and 0208	Moderate	No	Radiological	2
03	0040	Moderate	No	Radiological	2
03	0066 and 0451	High	No	Radiological, Chemical	2
03	0169	Moderate	No	Radiological	
08	0023	High	No	Radiological	2
21	0155	Moderate	No	Radiological	
21	0209	Extreme	No	Radiological, Chemical	2
36	0001	Moderate	No	Radiological	
41	0001 and 0004	Moderate	No	Radiological	
43	0001	Extreme	No	Radiological, Chemical	2
54	0033	High	Yes	Radiological	
54	0048	Moderate	Yes	Radiological	
54	0049	Moderate	Yes	Radiological	
54	0153	Moderate	Yes	Radiological	3
54	0215	Moderate	No	Radiological	3
54	0224	Moderate	No	Radiological	3
54	0226	Moderate	Yes	Radiological	3
54	0229	Moderate	Yes	Radiological	3
54	0230	Moderate	Yes	Radiological	3
54	0231	Moderate	Yes	Radiological	3
54	0232	Moderate	Yes	Radiological	3

[a] Construction type: 2 = noncombustible exterior with window exposures, 3 = combustible exterior.

Current sources of information were consulted for data on the relative quantities of radiological material at risk of potentially being impacted and released in an accident situation. By definition, only "Hazard Category 1 and 2" nuclear facilities can have offsite impacts from their radiological material inventories when considered on an individual basis. However, since site-wide accidents can involve releases from several facilities, Hazard Category 3 nuclear facilities and nonnuclear (radiological) facilities were also considered. Nuclear facilities that are rated Extreme, High or Moderate vulnerability from Table D–21 and that were within relatively high wildfire risk areas, were selected for quantitative contaminant risk assessment. Two additional facilities in TA-16, Building 205 (WETF) and Building 411 (Device Assembly) were also included, because, even though individual facilities may have low vulnerability, TA-16 is among the TAs at greatest risk from a wildfire.

D.5.4.2 Public Exposure from Burning Buildings

The individual exposures assume no sheltering inside buildings or vehicles and that no protective actions are taken by the individual at those locations. Although Area G is not in the direct path of the fire, it borders a canyon and could be susceptible to a canyon fire even in the absence of a site-wide fire. The results of the *1999 SWEIS* found that Area G contributed 75 percent of the total population exposure. Therefore, it was again included in the wildfire analysis.

D.5.4.3 Effects of Hazardous Chemicals

Vulnerable buildings and the outdoors in the fire path were screened for their chemical inventories and updated for 2004. Six of the 12 facilities included in the *1999 SWEIS* eliminated their chemical inventories. Only TA-3-66 increased its inventory from 11.5 pounds (5.2 kilograms) of hydrogen cyanide to 13.5 pounds (6.1 kilograms) of hydrogen cyanide. For fire-vulnerable facilities, the earthquake scenario chemical results are acceptable representations of the site-wide fire because the entire inventories are assumed to be released.

D.5.4.4 Onsite Workers and Offsite Population

In the event of a wildfire approaching from the south, LANL would begin evacuation of the southern area of LANL as soon as it was determined that the fire posed a threat, and would proceed north with the evacuation. Personnel deemed essential to shutdown operations would remain until such actions were completed. Some emergency response personnel and security personnel would remain at all times in some areas. In 1999 there were 10,200 LANL employees (including contractors), of which approximately 4,000 lived outside of Los Alamos County and 6,200 within Los Alamos County. The *1999 SWEIS* reported that the Main Hill Road (State Route 502) could evacuate 800 cars per hour, and the combination of the East Jemez and Pajarito Roads could evacuate another 800 cars per hour.

In the Cerro Grande Fire, it was decided that if the fire jumped Los Alamos Canyon, the entire town of Los Alamos would have to be evacuated. Shortly after noon on May 10, the fire jumped Los Alamos Canyon, which was the last natural barrier before the townsite, and, at 1:15 p.m., the County emergency personnel broadcast the directive for all of the people of Los Alamos to evacuate their homes immediately. Although some projections had indicated that it would take up to 12 hours to get all 12,000 Los Alamos residents down the mountain using the single road (State Route 502), the entire town evacuated in 4 hours, directed by the small police force. On May 10, 2000, the fire burned over 15,500 acres (62,700 hectares) in 9 hours—in other words, the Cerro Grande Fire consumed in 9 hours the same amount of acreage that the 1996 Dome Fire consumed in 9 days. By late afternoon, the wind-whipped 200-foot (60-meter) wall of flame reached the western edge of town; and, by 6 p.m. the first reports of loss of houses came in to the Emergency Operations Center.

In the aftermath of the Cerro Grande Fire, there was considerable interest in describing the potential radiological impacts of the fire itself and of the radionuclides of LANL origin that may have been dispersed during the fire. Radiological dose calculations performed based on air monitoring data were collected by the LANL AIRNET system during the Cerro Grande Fire. The dose calculated was the committed effective dose equivalent, which is the dose received during the 50 years following the inhalation of radionuclides. The inhalation dose to a maximally exposed individual in Los Alamos was 0.2 millirem (LANL 2001). A dose of similar magnitude was conservatively calculated for Rio Grande water use, chiefly from assumed irrigation during peak runoff from a storm event (LANL 2002). These doses can be considered in the context of exposure to naturally occurring radioactivity in the LANL area of at least 400 millirem per year (see Section 4.6.1.2 of this SWEIS).

All workers in threatened areas would be evacuated prior to arrival of the fire front. Aircraft crashes with fatalities have occurred while dropping slurry on wildfires. Firefighters on the ground are at risk if they enter an area without an alternate escape route, and there have been historical fatalities from such events. However, because life safety is given first priority over protection of property at LANL, it is not likely that there would be worker fatalities. Some firefighters and other emergency personnel could have significant but transient effects from smoke inhalation.

D.5.5 Wildfire Accident Impacts Analysis

There are no significant impact differences among the wildfire risks for the three alternatives, No Action, Reduced Operations, and Expanded Operations. Therefore, only a single set of wildfire impacts are presented. The radiological impact section, D.5.5.2, includes a discussion of the alternatives.

D.5.5.1 Facility Source Terms

A wildfire accident scenario was postulated for evaluation of impacts to onsite workers and the offsite population. Details of this scenario are given in the preceding sections. **Table D–22** shows the LANL buildings that could be affected by the wildfire, inventory of hazardous radiological materials, source term factors, and the estimated source terms.

D.5.5.2 Radiological Impacts

The estimated consequences for the public and workers as a result of a wildfire are shown in **Tables D–23** and **D–24** for each listed facility. The values shown assume that a wildfire has occurred and therefore do no reflect any credit for the probability of a wildfire occurrence. The estimated annual risks for the wildfire scenario are shown in **Table D–25**. The values shown in that table take credit for the probability of a wildfire's occurrence. The risk from a wildfire is seen to be dominated by the TA-54 waste storage domes. The second largest risk (although significantly less than the domes) is also from TA-54, DVRS.

Table D–22 Wildfire Accident Source Term Data

Accident Phase	*Nuclide*	*MAR (curies or grams)*	*MAR*	*Damage Ratio*	*Airborne Release Fraction*	*Respirable Fractions*	*Airborne Release Rate (per hour)*	*Leak Path Factor*	*Source Term (in units of MAR)*	*Release Duration (Delta T) (minimum)*	*Heat (mega-watts)*	*Release Height (meters)*	*Wake?*
Identifier: WILDF01. **Facility Name:** TA-3-66/451 (Sigma Complex).													
Fire	Depleted Uranium	grams	11,500,000	1	0.04	0.17	–	1	78,200	60	20	0	No
Suspension			11,000,000	1	–	1	0.00004	1	10,600	1,440	0.1	0	No
Identifier: WILDF02. **Facility Name:** TA-16-205 (WETF).													
Fire	Tritiated Water	grams	1,000	1	1	1	–	1	1,000	60	20	0	No
Identifier: WILDF05. **Facility Name:** TA-48-1 (Radiochemistry Laboratory).													
Fire	Plutonium Equivalent	grams	7.56	1	0.001	1	–	1	0.00756	60	20	0	No
Suspension			7.55	1	–	1	0.00004	1	0.00725	1,440	0.1	0	No
Identifier: DOMEP-Population. **Facility Name:** TA-54 Waste storage domes (all domes).													
Combustibles													
Burning Expelled in Lid Loss	Plutonium Equivalent	curies	37,100	0.333	0.001	1	–	1	124	60	–	0	No
Burning (in drums)			37,100	0.667	0.0005	1	–	1	12.4	60	–	0	No
Noncombustibles													
Burning	Plutonium Equivalent	curies	101,000	1	0.006	0.01	–	1	6.08	60	–	0	No
Total													
Burning (high-heat)	Plutonium Equivalent	curies	–	–	–	–	–	–	71.1	60	20	0	No
Burning (smoldering)			–	–	–	–	–	–	71.1	60	0.1	0	No
Impact Release			138,000	0.33	0.001	1	–	1	45.7	1	0	0	No
Suspension			138,000	0.33	–	1	0.000004	1	43.6	1,440	0	0	No

Accident Phase	*Nuclide*	*MAR (curies or grams)*	*MAR*	*Damage Ratio*	*Airborne Release Fraction*	*Respirable Fractions*	*Airborne Release Rate (per hour)*	*Leak Path Factor*	*Source Term (in units of MAR)*	*Release Duration (Delta T) (minimum)*	*Heat (mega-watts)*	*Release Height (meters)*	*Wake?*
Identifier: DOMEM-MEI. **Facility Name:** TA-54 waste storage domes (six western domes).													
Combustibles													
Burning Expelled in Lid Loss	Plutonium Equivalent	curies	22,800	0.333	0.01	1	–	1	76.1	60	–	0	No
Burning (in drums)			22,800	0.667	0.0005	1	–	1	7.61	60	–	0	No
Noncombustibles													
Burning	Plutonium Equivalent	curies	63,500	1	0.006	0.01	–	1	3.81	60	–	0	No
Total													
Burning (high-heat)	Plutonium Equivalent	curies	–	–	–	–	–	–	43.8	60	20	0	No
Burning (smoldering)			–	–	–	–	–	–	43.8	60	0.1	0	No
Impact Release			86,300	0.33	0.001	1	–	1	28.5	1	0	0	No
Suspension			86,100	0.33	–	1	0.00004	1	27.2	1,440	0	0	No
Identifier: WILDF08. **Facility Name:** TA-16-411 (Device Assembly).													
Fire	Uranium-238	grams	4,000	1	0.0005	1	–	1	2.00	60	20	0	No
Suspension			4,000	1	–	1	0.00004	1	3.84	1,440	0.1	0	No
Identifier: WDVRS06. **Facility Name:** TA-54-412 (DVRS).													
Ejected (from drums)	Plutonium Equivalent	curies	1,100	0.333	0.001	0.3	–	1	0.11	60	20	0	No
Burning (ejected material)			366	1	0.01	1	–	1	3.66	60	20	0	No
Burning (in drums)			1,100	0.667	0.0005	1	–	1	0.367	60	20	0	No
Total													
Fire	Plutonium Equivalent	curies	–	–	–	–	–	–	4.14	60	20	0	No
Suspension			363	1	–	1	0.00004	1	0.348	1,440	0.1	0	No
Identifier: WILDF10. **New Name:** TA-8-23 (Radiography).													
Fire	Plutonium Equivalent	curies	–	–	–	–	–	–	0.0026	60	20	0	No

MAR = material at risk, TA = technical area; WETF = Weapons Engineering Tritium Facility, MEI = maximally exposed individual, DVRS = Decontamination and Volume Reduction System.

Table D–23 Radiological Accident Offsite Population Consequences for a Wildfire Accident

Facility Impacted by Wildfire	MEI		Population to 50 Miles (80 kilometers)	
	Dose (rem)	Latent Cancer Fatality [a]	Dose (person-rem)	Latent Cancer Fatalities [b, c]
TA-03-66/451 (Sigma Complex)	0.00389	2.33×10^{-6}	4.75	0 (0.00285)
TA-16-205 (WETF)	0.0605	0.0000363	112	0 (0.0673)
TA-48-1 (Radiochemistry Laboratory)	0.00107	6.42×10^{-7}	0.436	0 (0.000262)
TA-54 (Waste storage domes)	1,930	2.32 [d]	91,300	55 (54.8)
TA-16-411 (Device Assembly)	1.48×10^{-6}	8.88×10^{-10}	0.000174	0 (1.04×10^{-7})
TA-54-412 (DVRS)	4.91	0.00295	1,160	0 (0.696)
TA-8-23 (Radiography)	0.000332	1.99×10^{-7}	0.562	0 (0.000337)

MEI = maximally exposed individual, rem = roentgen equivalent man, TA = technical area, WETF = Weapons Engineering Tritium Facility, DVRS = Decontamination and Volume Reduction System.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Increased number of LCFs for the offsite population, assuming the accident occurs; value in parentheses is the calculated result.

[c] Offsite population size is approximately 297,030 for TA-03-66/451; 404,913 for TA-16-205 and TA-16-411; 299,508 for TA-48-1; 343,069 for Waste Storage Domes and DVRS; and 349,780 for TA-8-23.

[d] Based on a dose-risk-conversion factor of 0.0006 LCF per rem, the indicated dose yields an LCF value greater than 1.00 as shown. This means that it is likely that an individual exposed to the indicated dose would contract a fatal latent cancer in their lifetime. For calculation purposes, the actual value is shown here; however, since the exposed recipient is an individual, the equivalent tables in Chapter 5, Section 5.12 show an LCF of 1.00.

Table D–24 Radiological Accident Onsite Worker Consequences for a Wildfire Accident

Accident	Noninvolved Worker at 110 Yards (110 meters)	
	Dose (rem)	Latent Cancer Fatality [a]
TA-03-66/451 (Sigma Complex)	0.0759	0.0000455
TA-16-205 (WETF)	0.333	0.000200
TA-48-1 (Radiochemistry Laboratory)	0.0155	9.30×10^{-6}
TA-54 (Waste storage domes)	8,730	10.5 [b]
TA-16-411 (Device Assembly)	0.0000173	1.04×10^{-8}
TA-54-412 (DVRS)	16.4	0.00984
TA-8-23 (Radiography)	0.00191	1.15×10^{-6}

rem = roentgen equivalent man, TA = technical area, WETF = Weapons Engineering Tritium Facility, DVRS = Decontamination and Volume Reduction System.

[a] Increased risk of an LCF to an individual, assuming the accident occurs.

[b] Based on a dose-risk-conversion factor of 0.0006 LCF per rem, the indicated dose yields an LCF value greater than 1.00 as shown. This means that it is likely that an individual exposed to the indicated dose would contract a fatal latent cancer in their lifetime. For calculation purposes, the actual value is shown here; however, since the exposed recipient is an individual, the equivalent tables in Chapter 5, Section 5.12 show an LCF of 1.00.

Note: To convert meters to feet, multiply by 3.28.

Table D–25 Radiological Accident Offsite Population and Worker Risks for a Wildfire Accident

Accident	Frequency (per year)	Onsite Worker: Noninvolved Worker at 110 Yards (100 meters) [a]	Offsite Population: MEI [a]	Offsite Population: Population to 50 Miles (80 kilometers) [b, c]
TA-03-66/451 (Sigma Complex)	0.05	2.28×10^{-6}	1.17×10^{-7}	0 (0.000143)
TA-16-205 (WETF)	0.05	9.99×10^{-6}	1.82×10^{-6}	0 (0.00336)
TA-48-1 (Radiochemistry Laboratory)	0.05	4.65×10^{-7}	3.21×10^{-8}	0 (1.31×10^{-5})
TA-54 (Waste storage domes)	0.05	0.05	0.116	3 (2.74)
TA-16-411 (Device Assembly)	0.05	5.19×10^{-10}	4.44×10^{-11}	0 (5.22×10^{-9})
TA-54 (DVRS)	0.05	0.000492	0.000147	0 (0.0348)
TA-8-23 (Radiography)	0.05	5.73×10^{-8}	9.96×10^{-9}	0 (1.69×10^{-5})

MEI = maximally exposed individual, TA = technical area, WETF = Weapons Engineering Tritium Facility, DVRS = Decontamination and Volume Reduction System.

[a] Increased risk of an LCF to an individual per year.

[b] Increased number of LCFs for the offsite population per year; value in parentheses is the calculated result.

[c] Offsite population size is approximately 297,030 for TA-03-66/451; 404,913 for TA-16-205 and TA-16-411; 299,508 for TA-48-1; 343,069 for Waste Storage Domes and DVRS; and 349,780 for TA-8-23.

Inventories at TA-48-1 (Radiochemistry Laboratory) and TA-8-23 (Radiography Facility) were assumed to be at the building limits. Radiological source material would be at these locations only during material testing. The impacts and risks presented in this section conservatively assume the presence of this material at the allowable limits.

The health risks in Table D–25 (and consequences in D–23 and D–24) are given for individual building releases; it is unlikely that a wildfire would impact all of these facilities. For the case of a wildfire impacting all of these facilities, the overall health risk to the general population, dominated by waste storage domes and DVRS releases, is 2.78 per year, that is, a mean of 14 cancer fatalities in the entire general population (out to 50 miles [80 kilometers] from each release) every 5 years of LANL operation. This risk can be contrasted with the more than 2,500 normally occurring cancer fatalities to this same population over 5 years (see Section 4.6.1, Public Health in the LANL Vicinity). Risks to individuals, on the other hand, cannot be summed, because a single individual would not be exposed to multiple facility releases. Instead, only releases upwind from the individual's location would result in exposure. The maximum health risk to the MEI from any facility's release for exposure at the nearest Pueblo boundary to the waste storage domes is 0.116 probability (almost 12 chances in 100) of an LCF per year of operation. It is highly unlikely that an individual would remain at this location during the entire wildfire event and, therefore, this risk is thought to be very conservative.

Each of the building releases was ascribed the same frequency of occurrence, 0.05. Section D.5.2 describes the potential of a wildfire affecting the various onsite technical areas. TA-54 is considered at a low (but not 0) risk of wildfire impacts relative to the other areas.

Tables D–23, D–24 and D–25 are strictly applicable to the No Action alternative. The Reduced Action Alternative would include a 20 percent reduction in high explosives processing and, likely, a reduction in risk from the Device Assembly Building. However, the consequences and risk from that facility are insignificant; a decrease in its risk would not affect the overall wildfire risk.

Replacement risks from wildfire accident impacts would result from implementation of the Expanded Operations Alternative. Transuranic waste storage at DVRS and waste storage domes in TA-54 would be moved to a new facility, TWCF, located in TA-50 or TA-63. The impacts from this new facility would be less than those of the existing facilities because of the new location and because less material would be stored, the rest being moved offsite. The entries in Tables D–23 through D–25 reflect present DVRS and waste storage domes operations because they would be active for part of the time period of interest and because their accident impacts bound the impacts of the new facility. TWCF accident impacts are described in Appendix H.

D.5.5.3 Chemical

The chemicals of concern at LANL facilities under the No Action Alternative, Reduced Operations, and Expanded Operations Alternatives are shown in **Table D–26**. These have been selected from a complete set of chemicals used onsite based on their quantities, chemical properties, and human health effects. The table shows the ERPG concentration values for which concentrations in excess of those could have harmful health or life-threatening implications as defined in the table's footnote.

Table D–26 Chemical Accident Impacts under Wildfire Conditions

			ERPG-2 [a]		*ERPG-3* [b]		*Concentration*		
Chemical	***Frequency (per year)***	***Quantity Released (pounds)***	***Value (ppm)***	***Distance to Value (meters)***	***Value (ppm)***	***Distance to Value (meters)***	***Noninvolved Worker at 100 Meters (ppm)***	***MEI at 1,000 Meters (ppm)***	***Nearest Site Boundary (12 m TA-43) (924 m TA-3)***
Formaldehyde at TA-43-1	0.05	14.1 liters (3.7 gallons)	10	141	25	89	19.7	0.23	Exceeds ERPG-3
Hydrogen Cyanide at TA-3-66	0.05	13.5 pounds (6 kilograms)	10	110	25	70	11.6	0.14	0.16 ppm

ERPG = Emergency Response Planning Guideline, ppm = parts per million, MEI = maximally exposed individual, m = meters, TA = technical area.

[a] ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective action (DOE 2004a).

[b] ERPG-3 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects (DOE 2004a).

Note: To convert meters to feet, multiply by 3.28.

Table D–26 shows the concentrations of each chemical, if it were released, at specified distances. The distances to the ERPG-2 and ERPG-3 levels of concern are 154 yards (141 meters) and 97 yards (89 meters), respectively for a formaldehyde release. The distances to the ERPG-2 and ERPG-3 levels of concern are 120 yards (110 meters) and 77 yards (70 meters) respectively for a hydrogen cyanide release. Depending on the magnitude of the release and plume characteristics, workers and members of the public could be exposed to harmful concentrations of each chemical within these distances from the point of release. Table D–26 also shows the estimated concentration of each chemical at a distance of about 110 yards (100 meters) from the release point where a representative noninvolved worker is assumed to be located. The seriousness of the exposure of a noninvolved worker at this distance is determined by comparing the concentration at that distance to the ERPG-2 and ERPG-3 levels of concern. Table D–26 also shows the estimated concentration at the nearest site boundary located at a distance of 13 yards

(12 meters) and 1,010 yards (924 meters) for TA-43 and TA-3 respectively, from the release point. The accident evaluation assumes a hypothetical member of the public is located at this site boundary. As in the case of the noninvolved worker, the seriousness of the exposure of a member of the public located at the nearest site boundary is determined by comparing the concentration at that distance to the ERPG-2 and ERPG-3 levels of concern. If concentration levels exceeding ERPG-2 and ERPG-3 were estimated to occur at distances beyond the site boundary, a segment of the offsite population could be exposed to harmful levels of the released chemical. The direction traveled by the chemical plume would depend upon meteorological conditions at the time of the accident.

D.5.5.4 Additional Environmental Effects

Firewater. Firewater (water used in fighting building fires) at nonnuclear facilities is captured by outdoor containment and temporary dikes erected for fire fighting. Firewater at nuclear facilities is captured by the drain system and is sent to TA-50 for processing. Conceivably, some radioactively contaminated water from the nuclear facilities could reach the outdoor environment, but would be of such small volume that it would not leave the building environs. If there were a fire at TA-50, most of the firewater would wash off down the roads. If fire trucks had to spray water, some of that water would go to the adjacent canyon. Resultant contaminated soil would be eroded, pending the return of vegetative cover. As with other contaminated soils, the environmental and human health threat from the new contamination would be assessed and mitigated.

Loss of Protective Cover. The charred plant remains following a severe wildfire are the only immediate visual consequences. The consequences of a wildfire are diverse, continuing through time and space, and frequently having significant changes in geomorphology and biological communities and processes. LANL is perhaps unique in potential consequences, because in addition to a rich presence of biological communities and cultural remains and resources, there exists soil-bearing legacy contaminants from historical operations.

Trees, grass, and herbaceous cover, and forest litter are important features in stabilizing soils by: (1) reducing the velocity and impact of falling raindrops; (2) reducing the velocity of runoff, thereby encouraging infiltration and discouraging its transport by water and wind; and (3) reducing runoff quantities. Loss of vegetative cover will create a setting that can have pronounced effects on flow dynamics, soil erosion, and sediment deposition. These changes also can have significant ramifications for plant and animal communities and cultural resources.

Runoff, Soil Erosion, and Sedimentation. It has been well established through studies around the world that runoff and sediment yields can dramatically increase following wildfires. Accompanying these physical changes are changes in the composition or quality of runoff water. At Los Alamos, these changes may be severe due to the steepness of the burned terrain and the high severity of the burn, creating water-shedding hydrophobic soils. These higher runoff quantities would be discharged into the Rio Grande where they would contribute to the overall floodwater storage of Cochiti Lake. Modified hydrologic conditions likely would cause some water courses that have only rarely had sufficient flows to reach the Rio Grande to increase their frequency of discharge.

Commensurate with higher runoff quantities and velocities would be an increase in soil erosion. Sheetflow would begin transporting soil suspended by rainfall droplet impact. Both rills and gullies would form on sloping ground surfaces with the first significant rainfall event. Higher channel volumes and velocities would promote both downward and lateral scouring of channels in the steeper portions of the watershed and sediment deposition in the lower portions. (These conditions depend on quantity of runoff discharges and resulting changes in channel hydraulics.) Headcutting would increase throughout the channel system. Delta formation would increase at the confluence of water courses tributaries to the Rio Grande, and added sediment would contribute to the depletion of the sediment reserve of Cochiti Lake.

The gradual establishment of ground cover would correspondingly retard soil erosion and a more stabilized hydrologic regime would return. Due to extensive rehabilitation after the Cerro Grande Fire, runoff, soil erosion, and sedimentation were minimized. To understand the possible impact to downstream water bodies, runoff events after the fire were monitored and sampled by the Laboratory. An extensive network of automated samplers and stream gages served as the cornerstone of this effort. Due to a general lack of intense "monsoon" type rainfall during the summer of 2000, severe runoff passing across LANL was limited to a single event on June 28. Record peak discharges were recorded for several drainages leading onto LANL during that event. For example, in Water Canyon above NM Highway 501, the estimated peak of 840 cubic feet (23,800 liters) per second dwarfed the prefire maximum of 0.3 cubic feet (8.5 liters) per second. Concentrations of most metals dissolved in stormwater are below the Environmental Protection Agency or New Mexico drinking water standards; however, a few (for example, aluminum, barium, manganese) are above the standards in many samples. Dissolved manganese concentrations increased by about 50 times above prefire levels; barium by 20. Concentrations of radionuclides dissolved in stormwater are slightly elevated or comparable to prefire levels.

Effects on Legacy Contaminants. Active erosion processes have moved some contaminants bound to sediment from the watershed into the Rio Grande, mainly as suspended sediment and bedload sediment. Conversely, many of the remaining legacy contaminants at LANL are present in situ, have not been transported far from their origin, or remain onsite. Water transport is a major mechanism for the transport of contaminants both in the dissolved and suspended sediment phases. Because vegetation acts to hold soil and reduce erosion, its loss (however short term) may significantly increase the potential for erosion and the transportation of contaminants. Some water courses have only rarely had sufficient flow to reach the Rio Grande, and because of this they have become "discharge sinks" for some contaminants. Increases in runoff amounts and frequency would increase the potential to remove and transport contaminants from the ground surface, and subsurface, and stream channels on LANL into the Rio Grande, and downstream to Cochiti Lake.

Effects on Biological Systems. Although fire is a natural part of biological systems, anthropogenic influences such as grazing, logging, and fire suppression have produced conditions that have pronounced adverse effects on forest ecosystems. Natural high-frequency, low-intensity fire regimes have been replaced with low-frequency, high-intensity fires that consume a higher percentage of vegetation. As reflected in other nearby areas that have experienced severe wildfires in the past (Water Canyon, La Mesa, Dome, and Oso Complex Fires), a wildfire at LANL would result in a period of disequilibrium with a reversion to early seral development and a corresponding change in animal use (Allen 1996). Fire debris, fallen trees, and needle cast would gradually begin to check erosion and develop soil conditions that would promote the establishment of grasses and herbaceous vegetation that would in turn further reduce erosion. This gradual reestablishment of ground cover would begin the dynamic process of seral progression toward a wooded or forested plant community.

A loss of forest or woodland habitat would result in a temporary loss of habitat for a broad spectrum of animals. As vegetation is reestablished, an altered community of animal species would follow, its composition changing with the evolution of the plant community. The pattern of burned vegetation would play a significant role in renewed wildlife use. Early plant communities of grasses and herbaceous growth can have a high biomass and species diversity, as exhibited by nearby areas affected by recent wildfires. This expansion of grass and herbaceous growth could provide additional forage for the large elk population in and around LANL and contribute to existing management concerns.

Impacts on threatened and endangered species (such as the Mexican spotted owl, *Strix occidentalis lucida*) would depend on several factors, such as the burn pattern, the time of day the burn occurs, the type of fire, topography, and if nesting is occurring. Threatened and endangered species have remained or returned to nearby areas that have experienced recent burns. Individual response to fire also would vary. Perhaps the most significant impact to threatened and endangered species precipitated by a wildfire could be the general disturbance caused by the firefighting effort itself (such as, fire fighting crews, aircraft, and vehicular traffic).

As discussed previously, increased runoff discharges would result in a commensurate increase in channel scouring, enlargement, and headcutting. This process, and any accompanying sedimentation, would have the potential to degrade or remove the limited riparian vegetation on LANL. Wetlands associated with water courses also would be affected, and perhaps several would be removed for a period of time because of changes in channel morphology. With the degradation of riparian vegetation and wetlands would be an associated reduction or loss of habitat for a variety of invertebrates, small and large mammals, amphibians, reptiles, and a diversity of birds.

Effects on Cultural Resources. LANL is located in a region of abundant and culturally significant prehistoric and historic resources, including traditional cultural properties. As stated, fire is a normal feature of the landscape and has played and continues to play a natural role in the culture of regional communities. Because of anthropogenic influences, the character of recent fires will be different from historic fires and will affect resources differently. Also, the need to protect property and life from wildfire will necessitate measures that can affect cultural resources.

As discussed, high intensity fires can burn an appreciable amount of ground cover and accelerate erosion. Surface erosion can physically disturb surface features and confuse and distort the contextual integrity of the site. More pronounced erosion in the form of gully formation and lateral bank cutting can permanently remove site features. Also, a high intensity fire can scorch organic remains located near the ground surface, decreasing their interpretive value. Historical structures can suffer through direct incineration. Damage to these resources also can occur as a consequence of vehicular traffic and mechanical disturbance (such as, bulldozers and fire trucks) and other soil disturbing activities connected with the firefighting effort.

Traditional cultural properties present on and adjacent to LANL include ceremonial and archaeological sites, natural features, ethnobotanical sites, artisan material sites, and subsistence features. These resources are an integral part of the landscape and almost certainly are and have been affected by natural fires. Because of the altered character of fires, these resources may be affected to a greater extent. Depending on the characteristics of these properties, they could either be permanently or temporarily affected by a wildfire and its subsequent ancillary effects, such as erosion.

D.5.6 Mitigation

After the *1999 SWEIS* was completed, actions were initiated to reduce the wildfire risk to major facilities with significant radiological inventories. Specifically, considerations were given to reducing the risk to low or very low for the following facilities:

- TA-3 Building 66/451, Sigma Complex
- TA-54 (Area G) Pads
- TA-21 Building 209, Tritium Science and Fabrication Facility
- TA-21 Building 155, Tritium Storage and Test Assembly
- TA-16 Building 205/205A, Weapons Engineering Tritium Facility

The planning, evaluation, and beginning of fire mitigation (described in DOE 1999b) that was completed prior to the Cerro Grande Fire undoubtedly contributed to minimizing the impacts to facilities and, possibly, human lives. There also is an ongoing, interagency, collaborative program to reduce the threat of catastrophic wildfire from occurring at LANL and the townsite by thinning and removing vegetation at the perimeter and in the surrounding Santa Fe National Forest and Bandelier National Monument. This will reduce the frequency and intensity of wildfires that could impact LANL.

D.6 Involved Worker Hazards

Facility workers generally fall into two groups: 1) noninvolved worker and 2) involved worker. Noninvolved workers have assigned duties on the site at a location beyond the general vicinity of an accident. The impacts of postulated accidents to the noninvolved worker are evaluated in this appendix and are presented in Chapter 5. Involved workers actively participate or support the operation of the facility directly involved with the Proposed Action. The analysis to determine involved worker risks are usually presented qualitatively due to the dynamics and potential worker proximity. In general, involved workers are protected by design safety features and operational procedures. Involved workers who are at the greatest risk of serious injury or fatality are those that are located in the immediate vicinity of where an accident takes place. Factors such as the time of the accident, an individual's distance from the accident and effects of shielding mechanisms are highly variable. Given the severity of some accidents, involved worker fatalities could be expected. The number of fatalities could range from zero to the maximum number of workers involved within the facility. For example, an accident involving spills and exposure to contamination could lead to an individual receiving a measurable dose, but not leading to a fatality, whereas in a severe earthquake accident, the involved workers are likely to be hurt and killed by the collapse of the building before they could be evacuated.

No attempt is made in this SWEIS to evaluate the involved worker effects of such accidents for the following reasons. There is limited information on the circumstances that cause such accidents and the hazardous conditions they involve are difficult to characterize in a manner that would differentiate between alternatives and provide meaningful information for decisionmakers. Modeling methods such as those used for radiological and chemical accidents exposures are not accurate at close distances. Quantitative or qualitative representation of such accidents would introduce data uncertainties that would complicate the decisionmaking process.

The analyses performed by authors of this SWEIS carefully considered provisions of National Environmental Policy (NEPA) Act, Council on Environmental Quality Guidelines and DOE NEPA Guidelines on acceptable procedures for estimating environmental impacts under conditions of data uncertainties and limited information. These provisions include the use of the "sliding scale approach" (DOE 2002b), which gives the analyst an opportunity to take into account specified key factors for determining an appropriate level of technical analysis for estimating impacts.

According to DOE NEPA Guidelines, the key factors to consider in applying a sliding scale approach to accident analyses include:

- Probability that accidents will occur
- Severity of the potential accident consequences
- Context of the proposed action and alternatives
- Degree of uncertainty regarding the analyses (for example, whether sufficient engineering design information is available to support detailed analysis) and
- Level of technical controversy regarding the potential impacts

More recent DOE guidance was also used for the preparation of this SWEIS (DOE 2004e).

D.7 Maximally Exposed Individual-Type Doses versus Distance

Sections D.3, D.4 and D.5 describe various facility and site-wide accident scenarios. These sections show the estimated exposure to the accident releases, were such accidents to occur. Exposure to radiological releases is described by dose, measured in rem, to an individual. Exposure to a population is generalized by summing the dose to each individual of that population; the population dose is thus measured in person-rem.

Exposures of the hypothetical noninvolved worker and MEI have been given in the previous sections. These are conservative representations of the exposure to any single individual from the plume that could emanate as a result of the occurrence of an accident. They are mean values, and thus include components of exposure to all of the meteorological conditions that could be experienced throughout the year. A number of assumptions are employed in the calculation of these exposures to individuals (see Table D–2) which result in conservatively large doses.

Foremost, is the assumption that the individual is always downwind of the plume. That is, the direction from the release to the individual is not taken into account (although the distance is); such a dose is sometimes called a sector independent representation of the exposure to the individual. In reality, were there to be an accident resulting in a release, the probability of the plume blowing toward a particular individual would be small. A second conservative assumption is that the individual lies directly in the path of the plume centerline, meaning the portion of the plume in which the release concentration is greatest. Again, even if the wind was blowing from the release in the general direction of the individual, the probability that the individual would be exposed directly to the plume centerline is small. Other conservative assumptions governing the calculation of exposure to the individual include his remaining at the nearest site boundary to the release (MEI) or 100 meters downwind from the release (noninvolved worker) for the duration of the event, no protection (that is remaining outside directly in the path of the plume), no deposition (thereby maximizing the inhalable plume concentration), no plume meander (that is, the individual is exposed to the plume centerline for the entire event), and use of an annual MET dataset (2003) which maximizes downwind plume concentrations.

The downwind location of the noninvolved worker, 100 meters from the hypothesized release, does not vary among scenarios. The downwind location at which each MEI exposure is calculated, that is, at the nearest site boundary to a hypothesized release, is specific to each scenario and release location. Although the scenarios and exposure locations correspond to the actions analyzed in this SWEIS, MEI-type doses at other locations could be of present or future interest. An example could be associated with the site-wide wildfire event. In a wildfire event, the location of the public and onsite personnel such as firefighters may not correspond to those associated with the other accident scenarios. Another example could be interest in the MEI dose at an onsite publicly accessible location, such as a road. These data would also be useful if NNSA were considering changing public accessibility to portions of the site or if the site boundaries were to change.

Table D–27 gives the MEI-type doses at various downwind distances for the accident scenarios considered in this SWEIS. The scenarios are grouped by their section in this and other appendices. Some of the action-specific scenarios, for example, MDA G explosion scenario, are reported both in this appendix and in the appendix discussing the action.

Table D–27 Maximally Exposed Individual-Type Doses versus Downwind Distance by Accident Scenario

Accident Scenario	*Identifier*	*MEI Location (Downwind Distance, in meters)*	*MEI Dose (rem)*	*Noninvolved Worker Dose (rem) at 100 meters downwind*	*Dose (rem) at Downwind Distance (in meters) of:*						
					250	*500*	*750*	*1,000*	*1,500*	*2,000*	*3,000*
Facility Accidents (Section D.3)											
RANT Outdoor Container Storage Area Fire (TA-54-38)	RAD01	Pueblo Boundary (402)	71.5	532	135	55	32.8	22.6	13.2	8.83	4.99
WETF Fire (TA-16-205)	WETFF	W. Jemez Rd (393)	5.91	8.92	7.3	5.08	3.66	2.75	1.73	1.13	0.628
WCRR Outdoor Storage Area Fire (TA-50-69)	RAD07	Trailer Park (1161)	1.1	44.7	10.8	3.79	2.08	1.37	0.767	0.479	0.256
Waste Storage Dome Fire (TA-54)	DOMEF	Pueblo Boundary (267)	419	1,950	461	157	83.6	53.8	29	18.1	9.33
Onsite Transuranic Waste Accident (TA-54)	DOMET	Pueblo Boundary (267)	186	761	202	86.6	52.2	36.1	21.2	14.1	7.98
Plutonium Facility Storage Container Release (TA-55-4)	RAD10	Royal Crest Trailer Park (1016)	2.5	35.8	14.5	6.47	3.84	2.56	1.44	0.915	0.494
Plutonium Facility Ion Column Rupture (TA-55-4)	RAD14	Royal Crest Trailer Park (1016)	1.28	9.09	5.42	2.89	1.84	1.31	0.777	0.494	0.267
DVRS Operational Spill (TA-54)	DVRS01	Site Boundary (227)	19.6	51.4	17.4	6.83	3.81	2.52	1.39	0.877	0.457
DVRS Building Fire and Spill Due to Forklift Collision (TA-54)	DVRS05	Site Boundary (227)	321	888	285	113	64.3	43	24.2	15.7	8.39
SHEBA Hydrogen Detonation	SHEBA	Pueblo Boundary (976)	0.877	15.4	4.35	1.93	1.2	0.854	0.521	0.357	0.205
CMR HEPA Filter Fire (TA-3-29)	CMR02	Town Site Boundary (924)	0.774	5.38	2.72	1.46	0.967	0.712	0.45	0.303	0.177
Fire Impacting Sealed Sources, CMR, Wing 9 (TA-3-29)	SEAL2CF	Town Site Boundary (924)	0.0987	1.21[a]	0.276	0.129	0.106	0.0958	0.0796	0.0645	0.0440
Explosion in a Pit at MDA G	MDAGEXP	Pueblo Boundary (355)	55.2	405	95.8	32.6	17.3	11.2	6.01	3.74	1.92
Site Wide Seismic Event (Section D.4)											
TA-3-29 (CMR) Seismic 1 & 2	CMR08	Town Site Boundary (924)	62.0	1940	470	161	85.6	55.1	29.6	17.8	9.11
TA-16-205 (WETF) Seismic 2	SIT02	W. Jemez Rd (393)	6.43	5.86	8.02	5.41	3.77	2.78	1.7	1.1	0.598

Accident Scenario	*Identifier*	*MEI Location (Downwind Distance, in meters)*	*MEI Dose (rem)*	*Noninvolved Worker Dose (rem) at 100 meters downwind*	*Dose (rem) at Downwind Distance (in meters) of:*						
					250	*500*	*750*	*1,000*	*1,500*	*2,000*	*3,000*
TA-18-168 (SHEBA) Seismic 2	SIT08	Pueblo Boundary (976)	0.0301	1.06	0.25	0.0852	0.0452	0.0291	0.0157	0.00975	0.00502
TA-21-155 (TSTA) Seismic 1 & 2	SIT09	State Route 502 (357)	0.00146	0.0111	.00259	.000877	.000464	.000298	.00016	.0000949	.0000477
TA-21-209 (TSFF) Seismic 1 & 2	SIT10	State Route 502 (363)	0.0125	0.0974	0.0228	0.00771	0.00408	0.00262	0.00140	0.000835	0.000420
TA-50-1 (RLWTF) Seismic 1 & 2	SIT11	Royal Crest Trailer Park (1082)	3.02	121	29	9.94	5.29	3.41	1.79	1.09	0.565
TA-50-69 (WCRR) Seismic 2	SIT13	Royal Crest Trailer Park (1161)	2.84	129	30.8	10.5	5.56	3.58	1.92	1.16	0.591
TA-54-38 (RANT) Seismic 1 & 2	SIT14	Pueblo Boundary (402)	64.2	576	136	46.4	24.7	15.9	8.55	5.32	2.74
TA-55-4 (Plutonium Facility) Seismic 2	SIT15	Royal Crest Trailer Park (1016)	4.21	47.9	21.4	10.1	6.2	4.31	2.51	1.58	0.847
TA-55-185 (Storage Shed) Seismic 1 & 2	SIT16	Royal Crest Trailer Park (1068)	5.98	239	56.9	19.4	10.3	6.63	3.55	2.14	1.10
TA-55-355 (SST Facility) Seismic 2	SIT19	Royal Crest Trailer Park (1048)	3.94	129	33.4	11.7	6.26	4.05	2.18	1.32	0.674
DVRS (PC-2 Seismic) Seismic 1	DVRS08	Site Boundary NNE (227)	2.76	10.1	2.39	0.821	0.438	0.283	0.153	0.0956	0.0495
DVRS (PC-3 Seismic) Seismic 2	DVRS12	Site Boundary NNE (227)	33.7	123	29.3	10	5.35	3.45	1.87	1.17	0.605
TA-54 Waste Storage Domes Seismic 2	DOMEM	Pueblo Boundary (267)	462	2150	509	173	92.1	59.3	31.9	19.9	10.2
Site Wide Wildfire Event (Section D.5)											
TA-03-66/451 (Sigma Complex)	WILDF01	Town Site Boundary (924)	0.00389	0.0759	.0202	.00831	.00497	.00358	.00251	.00218	.00204
TA-16-205 (WETF)	WILDF02	W. Jemez Rd (393)	0.0605	0.333	0.103	0.0503	0.0354	0.0337	0.0401	0.0479	0.0536
TA-48-1 (Radiochemistry Lab)	WILDF05	Royal Crest Trailer Park (677)	0.00107	0.0155	.00405	.00161	.000939	.000642	.000377	.000254	.000154
TA-54 (Waste Storage Domes)	DOMEM	Pueblo Boundary (267)	1,930	8,730	2,120	760	422	280	158	102	56.1

Accident Scenario	Identifier	MEI Location (Downwind Distance, in meters)	MEI Dose (rem)	Noninvolved Worker Dose (rem) at 100 meters downwind	Dose (rem) at Downwind Distance (in meters) of:						
					250	500	750	1,000	1,500	2,000	3,000
TA-16-411 (Device Assembly)	WILDF08	Site Boundary South of Facility (576)	1.48×10^{-6}	0.0000173	4.53×10^{-6}	1.80×10^{-6}	1.05×10^{-6}	7.12×10^{-7}	4.12×10^{-7}	2.72×10^{-7}	1.56×10^{-7}
TA-54 (DVRS)	WDVRS06	NNE of facility (227)	4.91	16.4	4.36	1.84	1.12	0.855	0.723	0.748	0.771
TA-8-23 (Radiography)	WILDF10	WSW Boundary (412)	.000332	.00191	.000592	.000289	.000203	.000194	.00023	.000275	.000308
Radiological Sciences Institute Accidents (Section G.3)											
Hot Cell Fire Involving Plutonium-238 in General Purpose Heat Source Modules	MRSC11	Royal Crest Trailer Park (941)	6.31	32.5	16.8	9.44	7.12	6.13	5.06	4.24	3.07
Seismic Induced Building Collapse and Fire Involving Plutonium-238 in General Purpose Heat Source Modules	MRSC16	Royal Crest Trailer Park (941)	29.6	152	79	44.3	33.4	28.7	23.7	19.9	14.4
Seismic Induced Building Collapse with No Fire Involving Plutonium-238 in General Purpose Heat Source Modules	MRSC15	Royal Crest Trailer Park (941)	19.4	171	82.1	40.9	25.6	18.1	10.8	6.87	3.74
Spill of Plutonium-238 Residue from 2-Liter Bottles Outside of Hot Cell	MRSC13	Royal Crest Trailer Park (941)	0.00662	0.0448	0.0236	0.0128	0.00848	0.0062	0.00385	0.00252	0.00141
Hot Cell Plutonium-238 Spill with No Confinement	MRSC14	Royal Crest Trailer Park (941)	2.12	14.3	7.56	4.11	2.71	1.98	1.23	0.808	0.452
Main Vault Fire	MRSC17	Royal Crest Trailer Park (941)	12.8	65.9	34.1	19.1	14.4	12.4	10.3	8.59	6.22
Material Disposal Area Remediation Accidents (Section I.5)											
Explosion at MDA G	MDAGEXP	Pueblo Boundary (355)	55.2	405	95.8	32.6	17.3	11.2	6.01	3.74	1.92

Accident Scenario	Identifier	MEI Location (Downwind Distance, in meters)	MEI Dose (rem)	Noninvolved Worker Dose (rem) at 100 meters downwind	Dose (rem) at Downwind Distance (in meters) of:						
					250	500	750	1,000	1,500	2,000	3,000
Fire at MDA B	MDABFIR	Nearest Boundary (45)	1.26	0.280	0.0656	0.0223	0.0118	0.00759	0.00406	0.00242	0.00122
Sealed Sources Accidents (Section J.3)											
Aircraft Crash at TA-54, Area G	SEAL1CM	Site Boundary NNE (267)	0.0843	0.517[a]	0.0910	0.0401	0.0244	0.0170	0.00996	0.00656	0.00363
Severe Earthquake and Fire at CMR	SEAL2CF	Town Site Boundary (924)	0.0987	1.21[a]	0.276	0.129	0.106	0.0958	0.0796	0.0645	0.0440
Severe Earthquake and Fire at TA-48	SEAL3CF	Royal Crest Trailer Park (941)	0.0980	1.21[a]	0.276	0.129	0.106	0.0958	0.0796	0.0645	0.0440
RH-Transuranic Waste Management Facilities Accidents (Section H.4)											
Explosion at MDA G RH-Transuranic Shaft 205	GS205EX	Pueblo Boundary (355)	0.31	2.27	0.538	0.183	0.0973	0.0626	0.0337	0.021	0.0108
Explosion at MDA G RH-Transuranic Shaft 206	GS206EX	Pueblo Boundary (355)	0.74	5.43	1.29	0.438	0.233	0.15	0.0806	0.0502	0.0258
Seismic Event Affecting RH-Transuranic in TWCF	DOMSEIS	Trailer Park (1,437)	0.0371	2.33	0.555	0.19	0.101	0.0649	0.0345	0.0209	0.0107
Seismic Event Affecting Transuranic Relocated from Area G Waste Domes to TWCF	DOMES	Trailer Park (1,437m)	28.8	1820	432	147	78.2	50.3	26.9	16.2	8.32

MEI = maximally exposed individual, rem = roentgen equivalent man, RANT = radioassay and nondestructive testing, TA = technical area, WETF = Weapons Engineering Tritium Facility, WCRR = Waste Characterization, Reduction, and Repackaging, DVRS = Decontamination and Volume Reduction System; SHEBA = Solution High-Energy Burst Assembly, CMR = Chemistry and Metallurgy Research Building, HEPA = high-efficiency particulate air (filter), MDA = material disposal area, TSTA = tritium systems test assembly, TSFF = Tritium Science and Fabrication Facility, RLWTF = Radioactive Liquid Waste Treatment Facility, WCRR = Waste Characterization, Reduction, and Repackaging Facility, SST = safe secure trailer, RH = remote-handled, PC = performance category, TWCF = Transuranic Waste Consolidation Facility.

[a] Doses include component from external exposure to source.

Note: To convert meters to feet, multiply by 3.2808.

D.8 MACCS2 Code Description

The MACCS2 computer code is used to estimate the radiological doses and health effects that could result from postulated accidental releases of radioactive materials to the atmosphere. The specification of the release characteristics designated a "source term," can consist of up to four Gaussian plumes that are often referred to simply as "plumes."

The radioactive materials released are modeled as being dispersed in the atmosphere while being transported by the prevailing wind. During transport, particulate material can be modeled as being deposited on the ground. The extent of this deposition can depend on precipitation. If contamination levels exceed a user-specified criterion, mitigating actions can be triggered to limit radiation exposures.

Atmospheric conditions during an accident scenario's release and subsequent plume transport are taken from the annual sequential hourly meteorological data file. Scenario initiation is assumed to occur equally likely during any hour contained in the file's dataset, with plume transport governed by the succeeding hours. The model was applied by calculating the exposure to each receptor for accident initiation during each hour of the 8,760 hour-dataset. The mean results of these samples, which therefore includes contributions from all meteorological conditions, is presented in this SWEIS.

There are two aspects of the code's structure basic to understanding its calculations: (1) the calculations are divided into modules and phases; and (2) the region surrounding the facility is divided into a polar-coordinate grid. These concepts are described in the following sections.

MACCS2 is divided into three primary modules: ATMOS, EARLY, and CHRONC. Three phases are defined as the emergency, intermediate, and long-term phases. The relationship among the code's three modules and the three phases of exposure are summarized below.

The ATMOS module performs all of the calculations pertaining to atmospheric transport, dispersion, and deposition, as well as the radioactive decay that occurs before release and while the material is in the atmosphere. It uses a Gaussian plume model with Pasquill-Gifford dispersion parameters. The phenomena treated include building wake effects, buoyant plume rise, plume dispersion during transport, wet and dry deposition, and radioactive decay and in-growth. The results of the calculations are stored for subsequent use by EARLY and CHRONC. In addition to the air and ground concentrations, ATMOS stores information on wind direction, arrival and departure times, and plume dimensions.

It is noted that dispersion calculations such as used in MACCS2 are generally recognized to be less applicable within 100 meters of a release than to further downwind distances (DOE 2004d); such close-in results frequently over predict the atmospheric concentrations because they do not take into account the initial momentum of the release nor the initial size of the release. The impacts of structures and other obstacles on plume dispersion are also not accounted for. Although most of the results presented in this SWEIS are for distances at least 100 meters downwind from a hypothesized release source, a couple (MEIs from CMR and MDA B) are not. The latter results should be interpreted in the above light.

The EARLY module models the period immediately following a radioactive release. This period is commonly referred to as the emergency phase. The emergency phase begins at each successive downwind distance point when the first plume of the release arrives. The duration of the emergency phase is specified by the user, and it can range between 1 and 7 days. The exposure pathways considered during this period are direct external exposure to radioactive material in the plume (cloud shine); exposure from inhalation of radionuclides in the cloud (cloud inhalation); exposure to radioactive material deposited on the ground (ground shine); inhalation of resuspended material (resuspension inhalation); and skin dose from material deposited on the skin. Mitigating actions that can be specified for the emergency phase include evacuation, sheltering, and dose-dependent relocation.

The CHRONC module performs all of the calculations pertaining to the intermediate and long-term phases. CHRONC calculates the individual health effects that result from both direct exposures to contaminated ground and from inhalation of resuspended materials.

The intermediate phase begins at each successive downwind distance point upon conclusion of the emergency phase. The user can configure the calculations with an intermediate phase that has a duration as short as 0 or as long as 1 year. In the zero-duration case, there is essentially no intermediate phase, and a long-term phase begins immediately upon conclusion of the emergency phase.

Intermediate models are implemented on the assumption that the radioactive plume has passed and the only exposure sources (ground shine and resuspension inhalation) are from ground-deposited material.

The mitigating action model for the intermediate phase is very simple. If the intermediate phase dose criterion is satisfied, the resident population is assumed present and subject to radiation exposure from ground shine and resuspension for the entire intermediate phase. If the intermediate phase exposure exceeds the dose criterion, then the population is assumed relocated to uncontaminated areas for the entire intermediate phase.

The long-term phase begins at each successive downwind distance point upon conclusion of the intermediate phase. The exposure pathways considered during this period are ground shine and resuspension inhalation.

The exposure pathways considered are those resulting from ground-deposited material. A number of protective measures, such as decontamination, temporary interdiction, and condemnation, can be modeled in the long-term phase to reduce doses to user-specified levels. The decisions on mitigating action in the long-term phase are based on two sets of independent actions: (1) decisions relating to whether land at a specific location and time is suitable for human habitation (habitability), and (2) decisions relating to whether land at a specific location and time is suitable for agricultural production (ability to farm). For the current SWEIS, no mitigation or special protective measures were assumed for the exposure calculations.

All of the calculations of MACCS2 are stored based on a polar-coordinate spatial grid with a treatment that differs somewhat between calculations of the emergency phase and calculations of the intermediate and long-term phases. The region potentially affected by a release is represented with a (r, Θ) grid system centered on the location of the release. Downwind distance is represented by the radius "r". The angle, "Θ", is the angular offset from the north, going clockwise.

The user specifies the number of radial divisions as well as their endpoint distances. The angular divisions used to define the spatial grid are fixed in the code. They correspond to the 16 points of the compass, each being 22.5 degrees wide. The 16 points of the compass are used in the United States to express wind direction. The compass sectors are referred to as the coarse grid.

Since emergency phase calculations use dose-response models for early fatalities and early injuries that can be highly nonlinear, these calculations are performed on a finer grid basis than the calculations of the intermediate and long-term phases. For this reason, the calculations of the emergency phase are performed with the 16 compass sectors divided into 3, 5, or 7 equal, angular subdivisions. The subdivided compass sectors are referred to as the fine grid.

Lifetime doses are the conventional measure of detriment used for radiological protection. These are 50-year dose commitments to a weighted sum of tissue doses defined by the International Commission on Radiological Protection (ICRP) and referred to as "effective dose equivalent." Lifetime doses may be used to calculate the stochastic health effect risk resulting from exposure to radiation. The calculated lifetime dose was used in cancer risk calculations.

D.9 ALOHA Code Description

Consequences of accidental chemical releases were determined using the ALOHA computer code (EPA 2004). ALOHA is an EPA and National Oceanic and Atmospheric Administration-sponsored computer code that has been widely used in support of chemical accident responses and also in support of safety and NEPA documentation for DOE facilities. The ALOHA code is a deterministic representation of atmospheric releases of toxic and hazardous chemicals. The code can predict the rate at which chemical vapors escape (such as from puddles or leaking tanks) into the atmosphere; a specified direct release rate is also an option.

ALOHA performs calculations for chemical source terms and resulting downwind concentrations. Source term calculations determine the rate at which the chemical material is released to the atmosphere, release duration, and the physical form of the chemical upon release. The term "cloud" is used in this document to refer to the volume that encompasses the chemical emission. In general, the released chemical may be a gas, a vapor, or an aerosol. The aerosol release may consist of either solid (fume, dust) or liquid (fog, mist, spray) particles that are suspended in a gas or vapor medium. Liquid particles are also referred to as droplets. The analyst specifies the chemical and then characterizes the initial boundary conditions of the chemical with respect to the environment through the source configuration input. The ALOHA code allows for the source to be defined in one of four ways (direct source, puddle source, tank source, or pipe source) in order to model various accident scenarios. The source configuration input is used to either specify the chemical source term or to provide ALOHA with the necessary information and data to calculate transient chemical release rates and physical state of the chemical upon release. ALOHA calculates time-dependent release rates for up to 150 time steps (DOE 2004c). ALOHA then averages the release rates from the individual time steps over one to five averaging periods, each lasting at least 1 minute (DOE 2004c). The five averaging periods are selected to most accurately portray the peak emissions. The five average release rates are inputs to the ALOHA algorithms for atmospheric transport and dispersion (DOE 2004c). ALOHA tracks the evolution of the mean concentration field of the five separate chemical clouds and calculates the concentration at a given time and location through superimposition. ALOHA limits releases to 1 hour.

Evolution of the mean concentration field of the chemical cloud is calculated through algorithms that model turbulent flow phenomena of the atmosphere. The prevailing wind flows and associated atmospheric turbulence serve to transport, disperse, and dilute the chemical cloud that initially forms at the source. For an instantaneous release or release of short duration, the chemical cloud will travel downwind as a puff. In contrast, a plume will form for a sustained or continuous release.

The wind velocity is a vector term defined by a direction and magnitude (that is, wind speed). The wind direction and wind speed determine where the puff or plume will go and how long it will take to reach a given downwind location. For sustained or continuous releases, the wind speed has the additional effect of stretching out the plume and establishing the initial dilution of the plume; it determines the relative proportion of ambient air that initially mixes with the chemical source emission. Atmospheric turbulence causes the puff or plume to increasingly mix with ambient air and grow (disperse) in the lateral and vertical direction as it travels downwind. Longitudinal expansion also occurs for a puff. These dispersion effects further enhance the dilution of the puff or plume. The two sources of atmospheric turbulence are mechanical turbulence and buoyant turbulence. Mechanical turbulence is generated from shear forces that result when adjacent parcels of air move at different velocities (either at different speeds or directions). Fixed objects on the ground, such as trees or buildings, increase the ground roughness and enhance mechanical turbulence in proportion to their size. Buoyant turbulence arises from vertical convection and is greatly enhanced by the formation of thermal updrafts that are generated from solar heating of the ground.

The ALOHA code considers two classes of atmospheric transport and dispersion based upon the assumed interaction of the released cloud with the atmospheric wind flow:

- For airborne releases in which the initial chemical cloud density is less than or equal to that of the ambient air, ALOHA treats the released chemical as neutrally buoyant. A neutrally buoyant chemical cloud that is released to the atmosphere does not alter the atmospheric wind flow, and therefore, the term passive is used to describe the phenomenological characteristics associated with its atmospheric transport and dispersion. As a passive contaminant, the released chemical follows the bulk movements and behavior of the atmospheric wind flow.

- Conversely, if the density of the initial chemical cloud is greater than that of the ambient air, then the possibility exists for either neutrally buoyant or dense-gas type of atmospheric transport and dispersion. In dense-gas atmospheric transport and dispersion, the dense-gas cloud resists the influences of the hydraulic pressure field associated with the atmospheric wind, and the cloud alters the atmospheric wind field in its vicinity. Dense-gas releases can potentially occur with gases that have a density greater than air due to either a high molecular weight or being sufficiently cooled. A chemical cloud with sufficient aerosol content can also result in the bulk cloud density being greater than that of the ambient air. Dense-gas releases undergo what has been described in the literature as "gravitational slumping."

Gravitational slumping is characterized by significantly greater lateral (crosswind) spreading and reduced vertical spreading as compared to the spreading that occurs with a neutrally buoyant release.

In addition to the source term and downwind concentration calculations, ALOHA allows for the specification of concentration limits for the purpose of consequence assessment (such as, assessment of human health risks from contaminant plume exposure). ALOHA refers to these concentration limits as level-of-concern (LOC) concentrations. Safety analysis work uses the ERPGs and TEELs for assessing human health effects for both facility workers and the general public. While ERPGs and TEELs are not explicitly a part of the ALOHA chemical database, ALOHA allows the user to input any value, including an ERPG or TEEL value, as the LOC concentration. The LOC value is superimposed on the ALOHA generated plot of downwind concentration as a function of time to facilitate comparison. In addition, ALOHA will generate a footprint that shows the area (in terms of longitudinal and lateral boundaries) where the ground-level concentration reached or exceeded the LOC during puff or plume passage (the footprint is most useful for emergency response applications).

The ALOHA code uses a constant set of meteorological conditions (such as wind speed and stability class) to determine the downwind atmospheric concentrations. The sequential meteorological datasets used for the radiological accident analyses were reordered from high to low dispersion by applying a Gaussian dispersion model (such as that used by ALOHA) to a representative downwind distance. The median set of hourly conditions for each site (that is, mean wind speed and mean stability) was used for the analysis; this is roughly equivalent to the conditions corresponding to the mean radiological dose estimates of MACCS2.

ALOHA contains physical and toxicological properties for the chemical spills included in the SWEIS and for approximately 1,000 additional chemicals. The physical properties were used to determine which of the dispersion models and accompanying parameters were applied. The toxicological properties were used to determine the levels of concern. Atmospheric concentrations at which health effects are of concern (that is ERPG-2 or ERPG-3 levels) are used to define the footprint of concern. Because the meteorological conditions specified do not account for wind direction (that is, it is not known *a priori* in which direction the wind would be blowing in the event of an accident), the areas of concern can be defined by a circle of radius equivalent to the downwind distance at which the concentration decreases to levels less than the level of concern. In addition, the concentration at 328 feet (100 meters) (potential exposure to a noninvolved worker) and at the nearest public access, typically the site boundary distance, (exposure to the maximally exposed individual) are calculated and presented.

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